A

PRACTICAL TREATISE

ON

HYDRAULIC MINING

IN

CALIFORNIA.

WITH

DESCRIPTION OF THE USE AND CONSTRUCTION OF

DITCHES, FLUMES, WROUGHT-IRON PIPES, AND DAMS;

FLOW OF WATER ON HEAVY GRADES, AND ITS APPLICABILITY, UNDER HIGH PRESSURE, TO MINING.

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THIS WORK IS DEDICATED

TO

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BY

THE AUTHOR.

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HYDRAULIC MINING IN CALIFORNIA.

CHAPTER I.

THE RECORDS OF GOLD-WASHING.

THE records of gold-washing have been traced almost to the prehistoric period. If any reliance can be placed upon the traditions which have descended to us, the yield from the auriferous deposits of the ancient world must have been enormous. It is a well authenticated fact that the Greeks carried on from the earliest times an extensive commercial intercourse with the people who lived north and east of the Euxine Sea, and thus drew largely on the gold-fields of Siberia, from which source the Gothic tribe of the Massagetæ also obtained their wealth. These gold deposits are supposed to have been situated in lat. 53° to 55° N., and are said to be identical with those worked by the Russians during the present century.

Asia Minor.—The mountains and streams of Phrygia and Lydia yielded gold in ancient times, and history has familiarized us with the wonders of the Pactolus,* from whose famous golden sands Crœsus is said to have derived his wealth. The sands of Asia Minor long since ceased to yield the precious metal.

Italy.—From a passage in Strabo (book iv. ch. 6, sec. 12) it appears that imperial Rome was "inundated with a glut" of gold from her northern mountains, the Alps. Polybius says that in his times gold-mines were so rich about Aquileia . . . that if you dug but two feet

* Herodotus, book v. c. 101; Strabo, book xviii.

below the surface you found gold, and that the diggings generally were not deeper than fifteen feet. . . . Italians aiding the barbarians in the working for two months, gold became forthwith one-third cheaper over the whole of Italy.*

Gold alluvia are known to exist in various localities in Upper Italy, but appear to be poor; and at the present time no gold-washing is carried on, except, perhaps, by a few individual workers. The sands of the Orco, the Jassin, the Po, and the Serio are estimated to have yielded three hundred ounces of gold in 1862.†

Spain and France.—The Romans are stated to have washed the sands of streams along the base of the Pyrenees.‡

The Phœnicians obtained gold from the bed of the river Tagus 1100 B.C., and washings are reported along this stream as late as 1833 A.D. The Douro sands were worked for gold by the Arabs until 1147 A.D. Up to the close of the fifteenth century the deposits of the river Ariége yielded annually about one hundred pounds of the precious metal. As late as 1846 gold-washings are reported along the Rhine between Strassburg and Philippsburg.

Africa.—At the present time but little gold is found within the limits of Abyssinia and Nubia, though the ancient Egyptians mined the precious metal in the latter country. The ancient mines described by Lenant Bey are situated in a district called Attaki, or Allaki, between Berenice and Suakin, on the Red Sea, one hundred and twenty miles distant from Ras-Elba. They are spoken of by Diodorus Siculus, and shown on one of the oldest topographical maps extant, preserved in Turin.

* "Siluria," foot-note, p. 449; also Pliny, book iii. c. 6, on the Great Value of the Mines of Italy.

† "Report on Precious Metals," W. P. Blake, Paris Universal Exposition, 1867.

‡ Strabo, book iv. p. 290; Cæsar, "De Bello Gallico," iii. 21; Jacob's "Inquiry into the Precious Metals," p. 53.

§ See "Agatharchides de Rubro Mari," in Diodorus, b. iii. c. 12–15; "Account of the Mines in Nubia and Ethiopia"; also Jacob's "Inquiry into the Precious Metals," ch. 11.

The earliest record of the Egyptian mines dates from the twelfth dynasty. The principal mines of Kordofan are between Darfur and Abyssinia. These mines are mentioned by Herodotus.

Nearly all the gold obtained in Africa has come from alluvial deposits. The country south of Sahara, from the mouth of the Senegal to Cape Palmas, contains numerous gold-bearing alluvions, which are worked by the negroes. The product of these mines is conveyed by caravans to Morocco, Fez, and Algiers, and forms a principal article of export from the Guinea coasts. Gold-dust is obtained also on the southeast coast, between lat. 25° and 22° S., opposite Madagascar, in the country of Sofala, by some writers identified with the region from which Solomon obtained his wealth. Recently alluvial deposits have been worked in the Transvaal, Leydenburg district (lat. 25° S., long. 35° E.), where coarse nuggets of gold, weighing as much as eleven pounds, have been found.

The approximate gold export of all Africa from 1493 to 1875, according to Dr. Soetbeer, amounted to £106,-857,000.

India.—In the Bombay Presidency gold-bearing deposits are reported to exist in the districts of Belgaum, Dharwar, and Kaladgi, in the southern Mahratta country, and the province of Kattywar. The sands in the streams arising from the Surtur series are auriferous, as are also those of the river Aji. The central provinces of India contain numerous small deposits of gold, but the number of gold-washings reported is comparatively very limited. The gold-fields of Madras have recently attracted considerable attention. The ancient mines of these regions have latterly been rediscovered. The known accumulated wealth of the ruling dynasties of southern India is supposed to have been obtained originally from these sources and from Malabar.

Brough Smyth, in his report on the Wynaad gold-

fields, 1879–80, states that the country is covered with tailings, an evidence of the industry of the Korumbas.

In the province of Mysore alluvions (containing very little gold) are known to exist near Betmangla, and gold quartz is being mined at present in different parts of the province.

A number of the rivers which have their sources on the borders of the Champaran district and Nepal, in the State of Travancore, contain auriferous sands, and gold-washing is carried on in these places at the commencement and termination of the rains. Auriferous sands occur in the Kumaun and Garhwal rivers. The sands of the river Koh, near Naginah, in the Maradabad district, are said to contain considerable gold. In Punjab all the rivers are reported to contain auriferous sands. Gold-washing has been practised in this district for many years, and was formerly a source of large revenue to the government.

Asiatic Islands.—The sands of the streams of Ceylon, Formosa, the Philippine Islands,* and some of the islands of the Indian Archipelago are known to contain gold; at Borneo extensive mining operations are carried on by the Chinese and the natives, over thirty thousand of the former being now employed in the gold-fields.

China.—In the beginning of the seventh century the celebrated Chinese traveller, Hiuen-thsang, describes the country north of the Kuen-Lun, towards the desert of Gobi, as an auriferous district. It is either here or in the Thibetan highlands, east of the Bolor chain, between the Himalaya and the Kuen-Lun, west of Iskardo, that Humboldt locates the land of gold sand spoken of by the Daradas (Dardar, or Derder), mentioned in the Mahabharata, and in the fragments collected by Megasthenes.†

According to Pumpelly ‡ gold is found in fourteen out

* See Jacob's "Inquiry into the Precious Metals," pp. 367–377.

† Humboldt's "Cosmos," vol. ii. pp. 511–516; Jacob's "Inquiry into the Precious Metals," p. 25.

‡ Extract "Geological Researches in China, Mongolia, and Japan," 1862–65. Raphael Pumpelly. Smithsonian Contrib., Washington, 1866.

of eighteen provinces of the empire. The greatest number of washings is in the province of Sze-Chuen (Se-Chuen) and along the branches of the Kuen-Lun mountain chain, which have an east and west trend, penetrating into Central China between the Wei River and the Sze-Chuen boundary. Placers are numerous at the base of the water-shed between Kwei-Chow and Hu-Nan, and through the centre of Shantung, from southwest to northeast. Most of these placers furnish coarse gold.

In the province of Shensi, on the northern frontiers at Hopootă and the Hala Mountains, much gold-dust is obtained annually. "Hundreds of thousands" of natives find employment in washing the sands of the river Kinsha-Kiang. On the banks of the Lou-tsze Kiang there are numerous gold-washings, and gold is reported to be found in almost all of the streams in the eastern portion of Shantung.

Consul Adkins (1877), at Newchwang, reports rich diggings in the valley of Chia-t'i-kou thirty miles long, and about five or six days' journey east by south from Kirwin and Newchwang.

Henry F. Holt's "Notes on Gold in China," published in Lock's work on "Gold," give very interesting information of the condition of gold-mining in this country, and Pumpelly furnishes a table of the placers.

Japan.—Gold was first discovered in Japan in 749 A.D.,* and the art of mining is said to have been introduced from China about the close of the same century. The gold-fields of the Musa valley are reported to have been worked by miners from Chikusen A.D. 1205. Japan has always been represented as a country rich in precious metals. Marco Polo, in the thirteenth century, said of Zipangu: "They had gold in the greatest abundance, its sources being inexhaustible." "Great abundance" of gold was reported by Kaempfer in 1727. The export of precious metals, chiefly gold, from 1550 to 1639 by the

* According to Dr. Geerts.

Portuguese was about $300,000,000, and from 1649 to 1671 the Dutch traders sent home $200,000,000, two-thirds of which was silver.* In the latter year the Japanese government forbade further export. The maximum gold production of this country was reached during the last half of the sixteenth century. Since that time the yield of gold has decreased steadily, and the product in 1874 is estimated by J. H. Godfrey, Chief Engineer of the Mining Office, at 12,000 ounces Troy.

The deposits from which this wealth was drawn were principally shallow placers. Prof. Munroe says that the present gravel-beds in Japan are of fluviatile origin, shallow, limited in extent, and uniformly poor. The richest deposits, near Yesso, contain less than seven cents per cubic yard, and the average of the best does not exceed five and one-half cents.†

Russia.—Russia possesses extensive gold-bearing deposits. The principal mining districts are those of the Ural,‡ the Altai region in western Siberia, western Turkistan, the northern and southern Yeniseisk fields, the circuit of Atchinsk and Minusinsk, Kansk and Nijneudinsk in the government of Irkutsk, Verkneudinsk, Barguzinsk in Trans-Baikalia, Olekminsk, the basin of the Lena, the country along the Amur, and Nerchinsk.

According to Lock ("Gold," p. 437) the total yield of all the Russian gold-washings from 1814 to 1860 inclusive (forty-seven years) amounted to 35,487 poods, or 1,548,661 pounds Troy of alloyed gold.§

In the reports of the United States Commissioners to the Universal Exposition at Paris, 1878, vol. iv. p. 248, James D. Hague states the approximate total production

* Griffis ("Mikado's Empire," p. 602) says that "Japan exported during the sixteenth and seventeenth centuries £103,000,000 in precious metals."

† See "Mineral Wealth of Japan," by Henry S. Munroe, E.M., Trans. Am. Inst. Min. Eng'rs., vol. v.

‡ Gmelin's "Journey through Siberia," 4 vols. Göttingen, 1751–2.

§ For production of gold in Russia see also Jacob's work, appendix pp. 414, 415, Report of the United States Monetary Commission, p. 571; Sir Hector Hay's "Parliamentary Report on Silver," 1876, App. 25.

of gold in Russia from 1753 to 1876 inclusive to be $730,-000,000. He also gives the following table showing the yield of the auriferous deposits during eleven years:

TABLE I.

Years.	No. of Explorations.	Quantity of sand and mineral washed. Poods.	Quantity of gold extracted. Poods.	Approximate value of product.
1867	878	968,423,325	1,650	$17,958,600
1868	993	1,177,288,244	1,711	18,622,524
1869	1,129	1,054,570,392	2,007	21,844,188
1870	1,208	983,475,095	2,157	23,476,788
1871	978	1,081,518,424	2,400	26,121,600
1872	1,055	1,044,027,585	2,331	25,370,604
1873	1,018	954,648,764	2,025	22,040,700
1874	1,035	937,578,045	2,027	22,061,868
1875	1,092	1,007,293,492	1,996	21,724,464
1876	1,130	1,022,543,362	2,054	22,355,736
1877	....	....	2,430	26,448,120

The aggregate of the poods is about 184,000,000 tons of 2,000 pounds avoirdupois, and the corresponding product is valued at $221,576,472, assuming that the weight of gold given is pure metal.

The Ural.—The gold-fields of the Ural extend from the sixty-first parallel northward about six hundred and ninety miles to the Arctic Ocean, and south into the Cossack and Baskir districts. The most valuable deposits have been found in the districts of Miask and Kashgar. At the former the largest nuggets have been obtained, and at the latter emeralds and pink topazes occur associated with the gold. Near Bogoslofsk is the celebrated mine of Peschanka. The production of these districts has steadily fallen off since 1860—a fact attributable to the impoverishment of the placers, which, nevertheless, are calculated by Bogoliubsky to represent a value of $61,660,000.

The Ekaterinburg group occupies the central Ural. The whole eastern slope of the Ural, north and south of

Ekaterinburg, is auriferous. The principal mine of this district is the Beriozofka, which has produced largely. The first washings were commenced here in 1814, but up to 1861 there was little or no improvement made in the method of working.

In the southern Ural lies the celebrated region of Zlataust, lat. 55° 11′ N., long. 77° 26′ E. The gold alluvion is found along the lateral streams which feed the Miask. This river was remarkable for its minerals and precious stones. The Miask placers were the richest in the Ural, but of late years their product has been very small.

The Altai.—Mining in the Altai is said to date from a very early period. The discovery of the alluvial deposits along the Fomiha River in 1830 gave a new impetus to gold-mining in Siberia, but richer fields have in later years attracted the miners, and the production of this district appears to have fallen to one-tenth of what it was twenty years ago.

Turkistan.—The auriferous deposits in western Turkistan, along the course of the river Tentek, are said to have been worked by the Chinese. Kuznetsof, a postal contractor, in 1868 tested some old Chinese diggings at Kizil-togoi, but from a summer's work at considerable expense obtained only one pound of gold. This has discouraged further mining. It is the opinion of many that the detritus of Turkistan is not at present worth working.

The Northern Yeniseisk.—The northern Yeniseisk fields were discovered in 1832. All the rivers partake of the character of mountain torrents. The most remunerative district was discovered in 1839, between the rivers Yenisei and Podkamenny Tungusska.

The Tèya River is about one hundred or one hundred and fifty feet wide. The gold deposits along its banks have been explored and found too poor to work. On the river Noiba placers were worked in 1842. The country

was abandoned subsequently, but reopened in 1854. The auriferous stratum lies in the bed of the river, or close to it, and varies in width from one hundred to three hundred feet, with a depth of from one to eight feet. These placers now produce annually a large amount of gold.

In the Yenashimo valley the alluvions vary from two hundred to fourteen hundred feet in width, and do not exceed eight feet in depth. They were discovered in 1851, and up to 1864 produced largely.

As early as 1840 the attention of gold-hunters was attracted to the alluvions along the Kalami, a tributary of the Yenashimo, and two years later work was commenced in this valley. These placers were very productive, although the auriferous material averages only from two and a half to eight feet in thickness. The mines on the Savaglikon are said to have produced from 1843 to 1864 $25,000,000.

In the valley of the Chirimba several deposits have been washed, and from the beds of the Aktolik a large amount of gold has been produced, the gravel having a depth of from seven to ten feet and varying in breadth from seven hundred to fourteen hundred feet. Mining operations in the northern Yeniseisk begin in May and continue until about the first week in September.

The Southern Yeniseisk.—In the southern Yeniseisk gold-fields the rivers have heavy grades. In many districts a scarcity of water prevails during the summer months. Only three of the river basins are noted for their auriferous alluvions, the others holding a secondary rank. The most important valley is that of the Udercy, where extensive gold-placers have been worked since 1845, but are now nearly exhausted. There are numerous placers along the river Murojnaia and its tributaries which flow into the southern Yeniseisk fields. The deposits have been worked since 1841.

The Great Pit River is the administrative boundary between the northern and southern systems. Its length is

about two hundred and thirty miles, and its valley is from two hundred and fifty to three thousand feet wide. The river in places is very narrow, forming rapids. On the Buruma and the Tujimo, feeders of the Gorbilka, a tributary of the Pit, there were formerly some washings. Below the Gorbilka the Pit is joined by the Penchenga, which, with its numerous feeders, especially the Greater Lower Ollonokon, is auriferous. The pay alluvion along the last-named tributary is confined to a channel from fifty-six to one hundred and seventy-five feet wide, and is from eight to twelve feet deep. In general the valleys of the Penchenga are considered too poor to work, though on some of the feeders washing has been carried on.

On the Untuguna, a feeder of the Ayakta, gold has been washed, and almandines, rubies (poor quality), tourmalines, and an abundance of zircon have been found.

Atchinsk and Minusinsk Fields.—The Atchinsk and Minusinsk fields, which have contributed for many years to the gold production of Siberia, have declined lately in importance.

Kansk and Nijneudinsk. — Kansk and Nijneudinsk, in the governments of Yeniseisk and Irkutsk, formerly produced a large amount of gold annually, but of late years their yield has been much reduced.

Verkneudinsk.—The Verkneudinsk district, which is southeast of Lake Baikal, produced up to 1874 some 17,640 pounds of gold, but in 1877 its production was only 480 pounds. North of this field are the auriferous tracts in the basin of the Lena, which have been worked since 1867.

Barguzinsk, Olekminsk.—The Barguzinsk district, in Trans-Baikalia, is imperfectly known. The Olekminsk circuit is situated in the basins of the Vitim and Olekma, tributaries of the Lena, where extensive mining operations have been carried on. This district is one of the most promising centres of gold-mining in Siberia, although the climate is very severe and the ground is frozen during the entire year.

Amur.—In the Amur region the gold-mining industry has been developed successfully, especially along the Zéhya, the Buréhya, and the Amgun rivers, but its progress has been checked by the scantiness of population. Two thousand men are said to be employed on the rivers Ura and Oldoi washing the alluvions, which are about seven feet thick. The placers of the Amur basin, in Trans-Baikalia, are a comparatively recent discovery. Gold is widely disseminated along the chief affluents of this river, and the deposits are easily worked.

This basin is reported to have yielded, up to 1875, a profit of £3,500,000. The auriferous deposits are estimated by Bogoliubsky to be one thousand miles long, three hundred and fifty feet wide, and to average five feet in depth, containing 16½ grains per 3,600 pounds. Only one-half of the basin is as yet explored.

Placers are found on the islands in the Sea of Japan, in Strélok Bay, and along the shore of the Okhotsk Sea.

Nerchinsk.—The placers in the Nerchinsk district are generally frozen. Detritus which yields less than 1 pennyweight per 1,800 pounds has been found unprofitable to work.

Brazil.—In 1543 gold was known to exist in Brazil (Walsh, vol. ii. p. 101), deposited in the beds of streams. The Indians at that period are said to have used it to make fish-hooks. Humboldt ("New Spain," vol. iii. p. 401) says that gold-placers were first discovered in 1577. The greatest prosperity of the gold-washings was in the middle of the eighteenth century.

The precious metal was first found in the Riberão, a tributary of the Rio das Mortes, or River of Death. This name commemorates a bloody encounter which took place between the gold-hunters, who, it is said, met and "set upon each other like famished tigers, impelled by the *auri sacra fames*." *

In the vicinity of the Riberão there is abundant evi-

* Walsh, "Travels in Brazil," vol. i. p. 104.

dence of the extensive search made for gold. The banks are everywhere furrowed and the vegetable mould has been entirely removed. Nothing remains but the red dirt, cut into squares by channels divided by narrow ridges. These channels were used for washing gravel, and were cut on an inclined plane. The water was introduced at the head of them, the dirt was then thrown in, and the lighter particles of clay were washed away, while the gold remained behind.*

The first placers in the country were called "cata." The surface dirt which contained gold was mined until the "cascalho," or cement-gravel, was reached. This was broken up by pickaxes, brought to the river, and washed. The first improvement introduced was to conduct the water to the ground and wash the gravel on the spot. These works were called "lavras," and hundreds of them were to be seen on the banks of the Rio das Mortes. A more improved method was practised subsequently.

In some districts water-wheels were used to assist in the drainage of the excavations, but were found so unmanageable that they were thrown aside, and the negroes were employed to pack off the gravel and rubbish on their heads in small casks.†

According to Dr. Soetbeer, from 1691 to 1875 (one hundred and eighty-five years) the gold production of Brazil amounted to 2,281,510 pounds Troy. By far the greater part was derived from alluvial deposits by river-washing. Hartt ‡ is of the opinion that there are still extensive surface deposits which, with modern appliances, can be worked successfully on a large scale, and limited washings now occur in almost every province in the empire.

Chili.—Chili contains numerous auriferous deposits, which, according to Schmidtmeyer, extend over most of the coast. The principal deposits are those near Copiapo,

* Walsh, vol. ii. p. 105. † Ibid., pp. 112, 113.

‡ "Geological and Physical Geography of Brazil."

Guasco, La Ligua, Petorca, Coquimbo, Tiltil, Caren, and Talca. The washings of Aconcagua and La Ligua have been the most productive and extensive. Gold-bearing drift has been reported as existing throughout the south of Chili, fifty miles back from the sea-coast, about the latitude of Coquimbo. Crosiner (Blake's "Report on the Precious Metals," 1867) mentions that gold deposits, which do not appear to have been formed by the decomposition of regular veins, are found in decomposed granite and red clay near Valparaiso. Similar deposits occur along the flanks of the Andes, the most extensive being east of Chillan.

During three hundred and thirty-one years, ending in 1875, the gold product of Chili approximated an annual average of $600,000, principally from the washings of river-beds. Recent attempts by American companies to work the deposits by the hydraulic process have not been attended with success, the yield of gold being much smaller than anticipated and the supply of water being too limited.

Bolivia.—The statistics of Dr. Soetbeer show that from 1545 to 1875 Bolivia produced gold to the amount of 646,800 pounds, or £41,013,300, derived principally from the washings of river-beds and shallow placers, the works on the river Tipuani being the most celebrated. The deposits seem to be widely distributed throughout the country, but detailed information concerning them is unobtainable.

Peru.—In Peru gold was gathered by the Incas in large amounts. Under the Spanish rule more than $33,000,000 are said to have been extracted from the mines and washings of Caravaya. The discovery of these placers was made in 1542, and the production of gold from this vicinity continued until 1767, when the town of San Gavan, containing four thousand families and a large treasure, was surprised and entirely destroyed by the Indians.

In 1849 the attention of miners was again attracted to Caravaya by reported discoveries of a great abundance of gold in the sands of one of the Caravaya rivers. Numbers of adventurers visited the country, but returned unsuccessful. There are gold-washings on the Chaluma River and its tributaries. The region of San Juan del Oro was once famous for its yield. The sands of the tributaries of the Purus are said to contain gold, and those of the Piquitiri are known to be auriferous.

Large deposits were worked with great profit up to 1820 in the province of Parinacochas, department of Ayacucho, along the banks of the Huanca-huanca River.

There are numerous auriferous deposits in the province of Sandia, department of Puno, some of which have been and still are being worked in a primitive style.

The present condition of the gold regions of Peru is unknown to the world at large. The most definite data of the production of gold from this country are given by Dr. Soetbeer, who says that from 1533 to 1875 the output aggregated £22,815,225. Paz Soldan's "Geographical Dictionary of Peru" contains much late information.

Venezuela.—At Caratal, State of Guayana, in Venezuela, small quantities of gold have been obtained from the alluvial deposits. This field has been described minutely by Le Neve Foster, from whose explorations the latest information is obtained. The deposits are situated about a hundred and sixty miles E.S.E. of Ciudad Bolivar. In the valley of the Mocupia gold-washing was carried on as early as 1857. Large placers have been recently discovered about fifty miles northeast of Caratal. The gold product of the Caratal mines from 1866 to 1879 inclusive is approximated at $14,000,000, and the mining region of Guayana is reported to have produced since 1874 about $1,250,000 annually.

The auriferous alluvions near the river Yuruari and along the banks of the Rio de Santa Cruz have been

worked for years by the Indians, and at Tesorero placer-mining is still carried on.

Expeditions from Europe in search of one of the many El Dorados have visited this country and sailed up the Orinoco. Humboldt ("Personal Narrative," vol. 3, pp. 23–44) gives an interesting account of this whole matter.

U. S. of Colombia.—The annals of gold-mining in the United States of Colombia are replete with interesting information. The famous El Dorado visited by Sir Walter Raleigh in 1517, and by the buccaneers in the seventeenth century, is situated in the province of Castilla del Oro. The Cana mines of this district, which were worked by slave labor, yielded largely, according to tradition, during the seventeenth century. The mines of Choco, on the western side of the Andes, are classed by Schmidtmeyer among the most productive in the west of America. These mines (which contain gold and platinum) are located on affluents of the river Atrato.

The Spaniards in former days carried on extensive mining operations near Malineca, on the river Tuyra. The Mina Real, in the Cerro del Espiritu Santo, at Santa Cruz de Cana, is said to have produced a large amount of gold. Late reports of this mine and mining district are very unfavorable, and cast grave doubts upon the correctness of the statements of its former production.

Auriferous alluvions occur in the vicinity of Piede Cuesta, at the head of the river Lebrija, in the province of Pampluna. All the rivers in Darien which flow directly into the Pacific are said to contain gold. Late reports (1881) state that the sands of the river Dibulla and the Rio de Sevilla are highly auriferous. The rivers of Santiago, Concepcion, Berrera, Zapaterito, San Antonio, and San Bartolomo, which were noted formerly for their gold-washings, continue to the present time to yield remunerative returns to the miner. Rich alluvions have been lately discovered below the Falls of San Jago, where ex-

tensive deposits are reported. Dr. Soetbeer states that the gold production of New Granada from 1537 to 1875 was £169,422,750.

Mexico.—Cortez's exploring parties in Mexico* obtained gold from the beds of rivers several hundred miles from the capital. Prescott says that gold, either cast into bars or in the form of dust, was part of the regular tribute of the southern provinces of the empire.† The gold product of Mexico at present is principally from quartz-mines, only a small amount being obtained by the "gambusinos," or native prospectors, who wash with the batea in the placers scattered here and there through the country. There are rumors of large bonanzas in the beds of streams in certain localities, and several attempts have been made to reach this wealth by turning the rivers, but hitherto without success.

The gold in the placers is sometimes distributed in the sands, in small quantities so far as known. In many districts the gambusinos obtain it, principally from crevices in the bed-rock, to reach which small shafts are sunk, often to a considerable depth.

Australasia.—The most important gold-fields of Australasia‡ are situated in the colonies of Victoria and New South Wales; Queensland and South Australia likewise contain gold alluvions.

Victoria.—The gold product of Victoria, according to the mineral statistics for 1880, aggregated 529,129 ounces, of which amount 299,926 ounces came from the alluvial deposits. Although the old placers have been worked extensively, and exhausted in many cases, the yield has been increased latterly by the opening up of new gold-producing areas and by improved methods of work. The total quantity of gold produced in Victoria from its discovery in 1851 to the end of 1880 is placed officially at

* See Helps, "Spanish Conquest of America"; also Las Casas, "History of the Indies."

† Prescott's "Conquest of Mexico," vol. i. p. 139.

‡ See "Gold," by A. G. Lock, from which work the above notes on Australasia are condensed.

£198,196,206, the mining operations extending over an area of twelve hundred and thirty-five square miles.

Ararat district contains large deposits of the upper and newer pliocene, considered to be of marine origin, but no gold in workable quantities has been found in any of these beds. The workable placers occur in the lower newer pliocene, whose origin is clearly a result of fluviatile agency. A fact worthy of mention is that in the neighborhood of Ararat, so far as yet explored, not a single well-defined quartz-vein has been found to contain pay gold.

In the northern portion of the Ararat fields the deposits attain a depth of from ninety to one hundred and fifty feet. In the Great Western mine the deposit, composed of older pliocene gravel-drift resting upon disintegrated granite, has been mined for a length of two miles and a width which in places exceeds twelve hundred feet. From accumulations of saline waters, and from undulations both horizontally and laterally of the bed rock, it is considered that "the lead" is simply a depression in a former sea-bottom.

In the Ballarat fields there are four clearly defined epochs of gold-drift, whose relative local positions are indicated by their names: "Oldest," "Older," "Recent," and "Most Recent." The "Oldest" period includes a deposit antecedent to the time at which the channels were eroded to their present depth. The "Older" embraces the deposit intervening between the lava-flows. Deposits of "Recent" age are those following immediately the uppermost lava flow. "Most Recent" drifts are those in most recently eroded gullies. There are three great lead systems near Ballarat, called the "Southern," "Western," and "Eastern." The "Southern" has been explored extensively; the "Western" is looked upon by some as the future hope of Ballarat in alluvial mining; the "Eastern" is but little known.

The alluvial deposits in Beechworth district have been

derived from the Silurian strata, not from the granite. The mining operations practised are simply those of ground-sluicing on a large scale. Considerable work has been done on the placers in Dargo district. The thickness of the gravel is from thirty to forty feet. On Mitchell River the gold-workings are confined to the creeks and the older alluvions on the banks. The Waranga fields, Sandhurst district, are among the oldest Victorian gold-fields, and have been worked since 1853. The most important of the workings are in the vicinity of Rushworth on a cement deposit, probably of the older pliocene. The gravel is shallow, the deepest shafts being only from thirty-five to fifty-five feet. This lead has yielded more than any other in the district. Nuggety Gully, Cemetery Lead, and Coy Diggings are also placers of note.

New South Wales.—The auriferous districts of New South Wales are considered the richest and most extensive in Australia. The gold-fields extend, with short intervals, the entire length of the colony, with a breadth of two hundred miles. Immense tracts in the interior still remain unprospected, and in time may prove to contain valuable gold-bearing deposits. Up to 1871 alluvial washings alone were carried on, gold-quartz mining being neglected. At this period sixteen thousand miners were at work. The product from 1851 to 1871 inclusive is stated by Reid to have been £26,457,160. The gold regions are all easy of access and are within two days' journey of the capital.

In Bathurst, Tambaroora, Turon, Lachlan, Mudgee, Southern, Peel, and Uralla districts water is scarce, and the discoveries of gold at Temora, Montreal, and Mount Browne have attracted a large number of miners from these places. Water is scarce at Temora also, but fortunately a large amount of very coarse gold has been found. The Montreal placers are near the sea-coast. The deposits are said to occur in two terraces, and give evidence of having been washed back by the sea.

In 1880, of the 13,430 gold-miners in the colony of New South Wales 11,403 were engaged in alluvial mining.

The Barrington field, on Back Creek, is about ten miles from the town of Gloucester. The principal gold deposits occur amid steep ranges, covered with thick forests and dense undergrowth. The creek has been worked for gold, but the results, though profitable, have not been remarkable. The water-supply is very uncertain, and in summer the creek ceases to flow.

The Kiandra gold field, on the table-land of Manecro, is situated about five thousand feet above sea-level, close to the highest mountains in the colony, around which are extensive deposits of auriferous gravel. Near Mount Table-Top the alluvions have been covered with basalt, and up to the present time this main deposit has been worked only to a limited extent.

The chief localities in which gold-mining has been carried on are those of Nine-Mile Diggings, New Chum Hill Diggings, Scotchman's Tunnel Claim, Bullock-Head Creek, and the Eucumbene River; also Township Hill Diggings, Eight-Mile Diggings, and Fifteen-Mile Diggings. Recent surveys show that water can be brought on certain of the Kiandra diggings, and here hydraulic mining is possible on a very limited scale. The rich placers developed by the sluicing operations toward Mount Table-Top have been compared by some writers to the gravel deposits near Placerville, California. Lachlan district was partially developed in the rush of the first mining excitement, and it is believed that only an insignificant proportion of the ancient river deposits was worked by the early miners.

Mount Werong is the site of one of the recent discoveries. The auriferous alluvion is said to be widely scattered. The gold has a water-worn appearance, and it is supposed that an old channel or lead formerly existed here. But as yet the country is only partially explored.

The Tallawang field contains one of the most ancient

auriferous alluvial deposits in the world; the gold occurs in the tertiary alluvial deposits, and in conglomerates in the coal measures the precious metal has also been found in paying quantities. At Clough's Gully the conglomerate is being worked and yields from 1 to 15 pennyweights per ton, and nuggets of 5 ounces are occasionally found.

Queensland.—The colony of Queensland lies to the north of New South Wales. Here thirty-one hundred square miles of auriferous alluvial and quartz ground were worked upon in 1876. The gold-fields occur on both sides of the main dividing range which separates the eastern and western waters, and on the spurs of the range which forms the water-shed to the Gulf of Carpentaria.

Charter's Towers fields are situated about the centre of the eastern portion of the colony. There are several small alluvial deposits, but the principal industry is that of gold-quartz mining.

In the Gympie district extensive quartz-mining is carried on, and some alluvial gold has been found in the Marengo gullies.

Gold quartz is mined in the Normanby region, but alluvial gold is sparsely distributed, the deposits not paying the cost of labor.

South Australia.—In South Australia gold is found in nearly every part of the colony, but the deposits are of very limited size. The bed of the river Torrens has yielded small quantities. The deposits of Barossa are said to resemble geologically and topographically Bendigo and other Victorian fields where the basaltic lava is absent. The principal deposit is probably of older pliocene age. The main lead in Spike's Gully shows a drift varying from twenty to a hundred feet in depth. In this drift, which consists of quartz pebbles, boulders, and ferruginous conglomerate, the gold is water-worn. The topography of the country is favorable for the construction of reservoirs at small expense, and sluicing could be

introduced without difficulty. The Echunga fields were discovered in 1852, but gave employment to a small number of gravel-miners only. Cement-crushing has been carried on in this district, but with little success. The Ulooloo gold-field contains some auriferous deposits composed of clay, sand, and shingle, forming banks of from six to twenty feet along the Ulooloo Creek. Water, however, is here very scarce.

In the northern territory, which extends from the Stapleton to the Driffield rivers, the auriferous deposits have been explored for a distance of about one hundred miles in length by twenty miles in width. There are no drift deposits. The alluvial gold occurs in small gullies and ravines, and occasional rich pockets are found.

New Zealand.—Gold was discovered in New Zealand in 1842. The alluvial deposits occur chiefly in the South Island, in the districts of Otago, Westland, and Nelson, where mining operations are carried on over an area of almost twenty thousand square miles. The detritus is found in the beds of the rivers, in large deposits of gravel from three hundred to five hundred feet deep, and in the sands along the sea-shore. The gold-drifts in Otago rest on the denuded surface of the parent rock, while in the Westland district they lie on tertiary rocks of marine origin. Fully two-thirds of the gold returned from this country is obtained from alluvial mining. The extent to which work is carried on may be judged from the fact that the miners have constructed over five thousand miles of water-races, with attendant tail-races and dams, at a cost approximating £300,000; this is independent of the government water-races and dams, which have cost £450,000.

Ground-sluicing is practised, and in some instances hydraulic mining has been introduced with heads of water from eighty to one hundred feet. The government has a tunnel eleven feet by seven feet, five thousand seven hundred and forty-four feet long, in course of construction,

having already built the open Sludge-channel, eight miles long, at Naseby. Besides these several tunnels have been built by private individuals.

At Gabriel Gully, Tuapeka, where the grade is very light, the hydraulic elevator is said to be working successfully; and in the river Clutha dredging machines are at work on the auriferous deposits. North of Charleston, on the coast-line, the beach sands which contain gold are worked by a colony of Shetlanders.

Extensive sluicing operations are carried on along the banks of the Molyneux, Kawarau, and Shotover rivers. At Tinkers and Drybread Diggings forty sluice-heads of water, with one hundred and thirty feet head, conducted through forty-five hundred feet of iron piping, are used to hydraulic the gravel. The depth of the deposits on the so-called Maori bottom approximates thirty feet. The resources of the province in auriferous drift are very great. Ulrich considers part of the old Clutha Lake basin where Bendigo Creek enters, and along the foot of the range upon which Bendigo reef occurs, as especially worthy of the attention of the drift-miner. Miller's Flat, between Arrow and Queenstown, a supposed old river-channel, is also considered rich.

The Thames field, on the east side of the Hauraki Gulf, is a narrow strip of land twenty-five miles long and from two to four miles wide. The gold in this district is obtained chiefly from quartz reefs. In Tapu district gold is found in considerable quantities in the decomposed soil on the slopes of the hills. It is usually flaky and not at all water-worn.

In Westland district the mines are classed as cement and alluvial workings. The cement is from one to six feet in thickness, and consists of quartz gravels which are found in connection with the coal series. The gold occurs in the lower portion of these beds. Alluvial workings are met with in all gullies cut in the auriferous series, but the gold is generally coarse. In the con-

glomerate formation the gold is caught in the brown sandstone bottom over which the conglomerate lies.

In the glacial drifts extensive claims have been worked and large quantities of gold have been obtained. These deposits are interesting, inasmuch as they derive their gold, in all probability, from the slates of which the glacial drifts are composed.

The black-sand beaches are composed of crystals of magnetic iron ore, which are found disseminated through the chloritic schist. The gold which is associated with the sand is supposed to have been derived from the Maitai slates, brought down in immense quantities by glaciers. This district includes the gold-fields of Wakamarina, Queen Charlotte Sound, and Wairau valley.

Extensive sluicing is going on at present in Wakamarina district. The ground is spotted and the gold is distributed unevenly. The Queen Charlotte Sound field is a quartz-mining district. The Wairau valley is an alluvial deposit, and is a comparatively new district. Gold occurs in almost all the gullies on the north bank of the Wairau River. The gullies are all very narrow. Some of the claims have proved very rich.

Canada.—In Canada gold is derived from the degradation of the upper Silurian and Devonian rocks. The Geological Commission, as early as 1852, determined the existence of auriferous alluvions extending over an area of more than ten thousand square miles. The principal deposits explored have been in the province of Quebec and in Nova Scotia. As notable may be mentioned the workings along the Chaudière River and its tributaries, the Du Loup and the Gilbert. Extensive deposits occur also to the southeast of the Notre Dame Mountains.

Small local deposits of high value have been worked, giving rise to great expectations, but as a whole the results have been unsatisfactory.

British Columbia.—In British Columbia gold was

discovered in 1858 on the Frazer River, above New Westminster, causing a great excitement and a "rush" of prospectors. San Francisco was nearly depopulated by the exodus, and it is estimated that one-sixth of the voters of California moved to the new placers. Gold was traced three hundred miles up the river to Cariboo. On the Peace River, two hundred and fifty miles still further north, gold was found. In 1872 discoveries in Cassiar district, eight hundred miles north of Victoria, caused the "Stickeen River rush." The Frazer River deposits were remunerative only to a limited extent and were soon worked out. In all the localities in this country the workings have been principally confined to shallow placers and river-bars, which are soon exhausted; but at Cariboo there are channels beneath the beds of the present water-courses. Shafts are sunk from the surface to the auriferous channels through a covering of clay and gravel. The bed of the ancient stream, when reached, is followed by drifts. While handsome returns have been occasionally made (in 1861 nearly a million of dollars were extracted), the expenses of working, there being much water to contend with, are so large that the operations have almost entirely ceased. In the more northerly districts the climate presents great obstacles and work can be carried on only during a few months of the year.

In Vancouver Island, in the Leech River district, gold has been found in a small area some twenty miles from Victoria.

Lock* estimates that from 1858 to 1880 (twenty-two and a half years) gold of the value of $45,140,889 has been extracted from (principally) the alluvions of British Columbia.

United States of America.—Outside of California (which will be treated in the following chapter), up to the present time, the alluvial deposits worked have been prin-

* "Gold," p. 38.

cipally shallow, and continued profitable development on a large scale is unknown.

New England.—Gold has been found in Vermont and New Hampshire, and alluvial deposits of limited extent have been exploited along the Green Mountains. But the production has been comparatively insignificant.

Virginia.—Alluvial gold has been reported as found in Virginia in Montgomery and Floyd counties, along Brush Creek. In Goochland County the hydraulic process was tried in 1877.

North Carolina, South Carolina, Georgia.—The Appalachian gold fields extend through the States of North Carolina, South Carolina, and Georgia. Gold was first discovered in 1799, and in 1829 the discovery of placers caused a great excitement. Two principal belts are known in North Carolina, one extending through Guilford, Davidson, Rowan, Cabarrus, and Mecklenburg counties; another through McDowell, Burke, and Rutherford counties; the latter has been traced into northern Georgia, where it forms the gold region in the vicinity of Dahlonega. The latter is the more western and more elevated, and contains richer placers.

The formation of these gold deposits has been attributed rather to the action of atmospheric influence than to deposition by large streams. The best placers were exhausted at the time of the discovery of gold in California, and more recent attempts to work them on a large scale and by the hydraulic process have not met with success.

Idaho.—Gold was first discovered in paying quantities near Pearce City, Idaho, in 1860. The Territory of Idaho, then a part of Washington Territory, was organized in 1862. The principal placers were those in the Boise basin, which first attracted the attention of miners in 1862, and on the Snake and Salmon Rivers. In 1865 the production of gold in the Territory amounted to $8,023,680, but the yield gradually decreased from that

year, and the placers produced in 1880 only $879,644. The Boise basin has been nearly exhausted, and the lower Snake River bars, which are quite limited in extent, are practically deserted. Above Fort Hall work is still going on. Salmon River was abandoned to Chinese labor in 1870.

Montana.—Gold was found on Gold Creek, in Deer Lodge County, Montana, in 1852, but the developments did not attract much attention until 1862, when a rush of immigration took place. The yield of the district up to 1870 is estimated at $24,000,000. Extensive works are still being carried on in this county. In Lewis and Clarke County the gulches and foothills are known to be auriferous to a great extent; they have yielded and are still yielding large amounts of the precious metal. Alder Gulch, in Madison County, was discovered in June, 1863, and in three years is said to have produced $30,000,000 (Raymond's "Report," 1870). Work is prosecuted still in this county and also in Meagher County.

Montana has contained some of the richest deposits known. Most of these have been worked as shallow placers, and in many of the locations much trouble has been experienced in obtaining water.

New Mexico.—Gold-placers are known to exist in New Mexico along the Rio Grande, from the Colorado line to the placers some forty miles south of Santa Fé, and also in the southwestern part of the Territory in the counties of Doña Ana and Grant. The latter have not been opened up to any great extent, although reports of exceedingly rich placers have long been current. The deposits along the Rio Grande have been described by Raymond ("Mineral Resources, 1874") and Prof. Silliman ("The Rio Grande Gold-Gravels"), who are authorities for the following statements.

The auriferous gravels extend southerly from the Colorado line along the Rio Grande valley some one hundred and fifty miles, over a width of about forty miles, between

the Sangre de Cristo Mountains on the east and the Continental Divide on the west. The southern portion, say seventy-five miles in lineal (northerly and southerly) extent, has been extensively denuded. The more northerly area has been eroded more or less, and contains accumulations of gravel, varying from fifty to six hundred feet in depth. Overflows of volcanic rocks cover and protect or interstratify the gravels in very many instances. The gravel consists chiefly of quartz and quartzite, and, to a much less extent, of syenite, porphyry, granite, gneiss, and slate débris, and evidently has been carried to its present location from only a short distance, probably from the Archæan rocks of the Sangre de Cristo and other southerly ranges of the Rocky Mountains. The gold is said to be diffused through the alluvions with great uniformity.

South of Santa Fé large Mexican grants contain extensive deposits of gravel, where gold was discovered in 1842, and whence in succeeding years large amounts of the precious metal are said to have been extracted. American companies have been recently formed to work all these deposits along the Rio Grande, but thus far the obstacles to success seem to have been very great.

Other States and Territories.—In various other States and Territories, as Colorado and Dakota, placer-mining has been carried on by small companies on a limited scale.

CHAPTER II.

HISTORY AND DEVELOPMENT OF PLACER-MINING IN CALIFORNIA.

FROM the auriferous deposits of the State of California \$1,100,000,000 have been extracted during the last thirty-five years.*

The magnitude of the mining operations required to produce this enormous yield is but little known to the general public. The continuous flow of gold bullion has, however, made the State famous and attracted the attention of political economists everywhere.

First Mention of California.—The first mention of the name "California" occurs in connection with a supposed great island where gold and precious stones were found in abundance, described in a romance called "Las Sergus de Esplandian," published in Spain A.D. 1510. The followers of Cortez had chimerical ideas of some hidden El Dorado, and, strange to say, they applied the name California to that unknown country north of Mexico with which they associated the notion of a region of fabulous wealth.

Discovery of Lower California.—The first expedition sent out by Cortez, in 1534, discovered what is now called Lower California. According to Father Venegas, this expedition, numbering some seven hundred souls, was fitted out at the port of Tehuantepec in the year 1537, and sailed north to the head of the gulf of California, but never reached the line which marks the southern boundary of the State of California.

Contemporaneously with the departure of this party "four persons, named Alvarez Nuñez, Cabeza de Vaca,

* Up to 1883. See Appendix A.

Castillo, and Dormentes, with a negro named Estevancio," arrived at Culiacan, on the gulf of California, from the peninsula of Florida. These were the sole survivors of the three hundred Spaniards who in 1527 landed with Pamfilo Narvaez on the coast of Florida with the intention of conquering that country. Nuñez subsequently conducted the expedition which discovered the Rio de la Plata and effected the first conquest of Paraguay.

Early Explorations.—In 1542 Mendoza, Viceroy of Mexico, sent Rodriguez Cabrillo, a Portuguese, to survey the west coast of California. He explored the coast, naming the numerous headlands, the most northerly of which, in lat. 40° N., he called Cape Mendocino. Thence he proceeded further north to lat. 44°, which he reached March 10, 1543.

In 1578 Sir Francis Drake entered the Pacific and sailed north as high as lat. 48°. According to Hakluyt's account of the voyage, Drake spent five weeks in June and July, 1579, in a bay near lat. 38° N.

First Mention of Gold.—The narrative says: "Our General called this country New Albion. . . . There is no part of the earth here to be taken up wherein there is not a reasonable quantitie of gold and silver." It is difficult to reconcile this statement with the facts as known at present, since in lat. 38° N. neither gold nor silver exists in "reasonable quantitie" near the ocean. This is, however, remarkable as the first mention of gold in California proper.

In 1602 the Count de Monte Rey, Viceroy of New Spain, by order of the king, sent Sebastian Viscayno on an exploring expedition. He sailed from Acapulco, May 5, 1602, with two vessels and a tender, with Admiral Gomez in command. The expedition, composed of a large number of men, was fully equipped for one year's voyage. Three barefooted Carmelites accompanied the party. and the several departments were entrusted to distinguished officers, volunteers from Brittany.

After a struggle with northwest winds, on November 10, 1602, the fleet entered the harbor of San Diego,* and, having spent a few days there, the expedition again sailed north. December 16, 1602, anchor was cast in Monterey Bay, which was named in honor of the viceroy. January 3, 1603, the fleet weighed anchor, and a period of one hundred and sixty-six years elapsed before this bay was revisited. January 12 the fleet passed the bay of San Francisco and anchored behind a point of land called "La Punta de los Reyes," but did not enter San Francisco harbor. The voyage was subsequently continued as far as lat. 43° N., from which point the fleet returned to Acapulco.

First Mission established in Lower California.—In 1697 the first permanent mission was established by the Jesuits at Loreto, Lower California. "These people," says the historian, "with patient art and devoted zeal, accomplished that which had defied the energy of Cortez and baffled the efforts of the Spanish monarchy for generations afterwards."

First Mission in Upper California.—In 1769 the Jesuits were banished from Lower California. On the 9th day of January, 1769, an expedition set sail from La Paz, in Lower California, to rediscover San Diego and Monterey. The vessels stopped at Cape St. Lucas, and left that point February 15 of the same year. On the 1st of July, 1769, a land expedition which had started shortly after the vessels had set sail from Cape St. Lucas, under the immediate charge of Padre Junipero Serra, reached San Diego and established the first Franciscan mission in Upper California.

Notwithstanding the facts revealed by the many expeditions, the geographers of that day still persisted in describing California as an island extending from Cape St. Lucas, at the tropic of Cancer, to lat. 45°

* An interesting account of this voyage is given by E. Randolph, Esq., "Memoirs of the Society of California Pioneers."

N.,* and it was not until Father Begert's map was published at Manheim, in 1771, that California was relieved of its insular character.

Early Discoveries of Placers.—At different times between 1775 and 1828 small deposits of placer gold were found by Mexicans near the Colorado River. In 1802 a mineral vein supposed to contain silver was found at Olizal, in the district of Monterey. In 1828 a small gold placer was discovered at San Isidro, in what is now known as San Diego County.

Forbes, in his history of California, in 1835, says: "No minerals of particular importance have yet been found in Upper California, nor any appearance of metals."

In 1838 the placers of San Francisquito, forty-five miles northwest from Los Angeles, were discovered. These deposits were neither rich nor extensive, but were worked steadily for twenty years.

In 1841 Wilkes' exploring expedition visited the coast, James D. Dana, mineralogist, accompanying the party. In the following year, in his work on mineralogy, Dana mentions that gold was found in the Sacramento valley, and that rocks "similar to those of the auriferous formations" were observed in southern Oregon.

May 4, 1846, Thomas O. Larkin, United States Consul at Monterey, said, in an official letter to James Buchanan, Esq., then Secretary of State: "There is no doubt that gold, silver, quicksilver, copper, lead, sulphur, and coal mines are to be found all over California, and it is doubtful whether, under their present owners, they will ever be worked."

On the 7th of July, 1846, the American flag was hoisted at Monterey and the country taken possession of by the United States.

* See Ogilvy's "America: being the latest and most accurate Account of the New World," published in London in 1671. California is there laid down as an island, extending from Cape St. Lucas to lat. 45° N. See map by Capt. Shelvocke, R.N., "Voyage around the World by way of the South Sea," published in London in 1726. See map published in Venice in 1546, Independent Order of Odd Fellows' Hall, San Francisco.

Marshall discovers Gold at Coloma.—January 19, 1848, James W. Marshall, while engaged in digging a race for a saw-mill at Coloma (thirty-five miles east from Sutter's Fort), found some pieces of yellow metal which he and the half-dozen men working with him at the mill supposed to be gold. "He felt confident that he had made a discovery of great importance, but he knew nothing of either chemistry or gold-mining, and he could not prove the nature of the metal or tell how to obtain it in paying quantities. . . . So Marshall's collection of specimens continued to accumulate, and his associates began to think there might be something in his gold-mine after all." *

In the middle of February, Bennett, one of the party employed at the mill, went to San Francisco and returned with Isaac Humphreys, a man who had washed gold in Georgia, and who, after a few hours' work, declared the mines to be richer than those of his own State. By means of a rocker he obtained daily about one ounce of gold, and soon all the hands of the mill were rocking for the precious metal.

The record of the discovery of gold, as related by Parsons in his biography of Marshall, is somewhat different from that published by Browne, and gives to Marshall alone the credit of the discovery.

Other Gold Discoveries.—Pierson B. Redding, the owner of a large ranch at the head of the Sacramento valley, visited the mining works at Coloma, and immediately resolved to commence washing on his own property, which he thought was in a similar formation, and in a few weeks he had begun mining on a bar on Clear Creek, nearly two hundred miles northwest from Coloma. This example was followed by John Bidwell, who, having seen Sutter's works, commenced prospecting on the bars of the Feather River, seventy-five miles northwest from Coloma.

* See "Reports upon the Mineral Resources of the United States," by J. Ross Browne, 1867.

In March, 1848, the treaty of Guadalupe-Hidalgo was made, and Mexico ceded California to the United States. By the end of the same year mines were opened at far-distant points. Miners were at work in every large stream on the western slope of the Sierra Nevada, from Feather River to the Tuolumne, a distance of one hundred and fifty miles.

First Publication of Gold Discoveries.—The first printed notice of the discovery of gold appeared in the *Californian* (?), a newspaper published in San Francisco, on March 15, 1848. On May 29 the same paper announced that its publication would be suspended, the whole population having betaken itself to the mines.

In 1849 the placers of Trinity and Mariposa were opened. At this period hired men were the exception, every man working for himself, and rocker claims were very abundant. In 1850 the deposits of Klamath and Scott's Valley were discovered.

First Attempt to build Ditches.—The chief want of the placer-miner being water, the first noteworthy attempt at ditch-building was made in March, 1850, at Coyote Hill, Nevada County.

In the spring of the same year gold was reported as lying in heaps on the banks of Gold Lake, near Downieville. This caused a tremendous excitement and a rush of miners to that locality. In a few weeks thousands returned from the lake poorer than when they started.

On September 9, 1850, California was admitted into the Union as a State. The number of persons then engaged in mining was estimated at fifty thousand. River-mining at this period occupied a prominent place in the industries of the State.

First Use of the "Long Tom."—The winter of 1849-50 was very stormy and comparatively little work was done in the rivers or creeks, but in the spring of 1850 mining was resumed on those bars which were subject to overflow only at extreme high water. The pick, shovel.

rocker, and wheelbarrow were the only implements then in use. Towards the end of 1850 the "Long Tom" was introduced.

Discovery of Gold-Quartz Veins.—Extensive prospecting at this period for the sources of these gravel deposits led to the discovery of gold-quartz veins, the most noted of which was the Allison Ranch mine in Nevada County. In 1851 came the rush to Gold Bluff, lat. 41° N.

The work on dry bars gradually led to mining the river bottoms, which was first undertaken by means of wing dams. Later the more venturous miners turned entire streams from their courses by means of flumes or ditches.

First Working of Deep Deposits.—Simultaneously the miners "pushed back" from the shallow placers to deep deposits which were worked by means of the tom, and with the advent of sluices in 1851 the low hill gravels were attacked and successfully mined. Coincident with the introduction of the sluice and washing of hill gravels came the employment of hired men in placer diggings.

Sluicing.—The deep deposits of auriferous gravel were relatively poorer than the shallow placers, and open cuts, preparatory to sluicing, were requisite; a large supply of water was a *sine qua non*, ditches became a necessity, labor was in demand, but without capital nothing could be accomplished.

The sluice revolutionized gold-washing. With the exhaustion of the surface diggings the river towns fell into decay, and those mountain districts where the deep auriferous beds were found soon became the prosperous counties of the State.

First Use of the Hydraulic Method.—It was evident that the sluices ran dirt faster than the shovellers could supply it; labor was expensive—men receiving from $6 to $8 per diem—and the claims were poor compared with the washings of 1849–50. In 1852 Edward E. Mattison, of Connecticut, with a view to economizing

labor, used a stream of water under pressure. For this purpose water was conveyed to the claim in rawhide hose and discharged through a wooden nozzle against a bank. Torn by the water, the earth was carried into the sluices and shovelling was thus avoided. A large saving in the cost of mining was effected, a greater amount of material being washed in a shorter time. This was the first step in hydraulic mining.

Canvas Hose.—Mattison's experiments were immediately appreciated and his method adopted. Hose made of canvas was widely used, the canvas being strengthened by netting and bound with rope.

Iron Pipe.—Towards the end of 1853 pipes made of light sheet iron were introduced as a substitute for canvas hose. The first iron pipe was used by R. R. Craig, on American Hill, Nevada County. It consisted of about one hundred feet of stove-pipe. In 1856 a firm in San Francisco commenced the manufacture of wrought iron pipes for hydraulic mining, and during the years 1856 and 1857 a large sheet-iron pipe forty inches in diameter was laid for a water-conduit across a depression at Timbuctoo, in Yuba County.

Inverted Siphons.—In 1869 a wire suspension bridge across the Trinity River, near McGillivray's, was constructed by Joseph McGillivray. This bridge supported a fifteen-inch wrought-iron pipe which conducted water from a ditch situated at an elevation of about two hundred and forty feet above the bridge. The length of the pipe was nineteen hundred and eighty feet, and the outlet was one hundred and thirty-three feet below the level of the inlet. In the fall of 1870 the Spring Valley Company, of Cherokee, Butte County, laid the first large "inverted siphon" in the mining regions. The siphon was made of wrought iron, riveted. It was thirty inches in diameter and fourteen thousand feet long, crossing a depression of nearly one thousand feet.

Improved Nozzles.—With the substitution of sheet-

iron pipe for canvas it was found necessary to retain a short piece of canvas hose in order to obtain a flexible discharge piece. This was inconvenient and troublesome. The ingenuity of miners was aroused, and the result was the introduction of a nozzle called the Goose Neck, which was a flexible iron joint formed by two elbows working one over the other.

The first Rifle.—The radius-plate, or rifle, was patented by C. F. Macy in 1863, and was subsequently introduced and used in all metallic jointed discharge pipes which had elbows.

The next improved hydraulic nozzle was invented by the Messrs. R. R. & J. Craig, of Nevada County. It was called Craig's Globe Monitor. This nozzle proved a success and was adopted at once by the miners. Subsequently the Hydraulic Knuckle-joint and Nozzle was invented by H. Fisher, of Nevada County, and took the place of the Craig machine. In 1870 Mr. Richard Hoskins obtained a patent for his Dictator, a one-jointed machine, having an elastic packing in the joints instead of the metallic faces. A few months later Hoskins patented the nozzle called the Little Giant, which was an improvement on the Dictator, and has to a great extent superseded the older inventions.

Deflector.—The next advance in hydraulic discharge machines was an attachment to the nozzle called the "deflector," the invention of Mr. H. C. Perkins, and patented May, 1876. This is a short piece of pipe, about an inch larger in diameter than the nozzle, attached to the latter by a gimbal joint and operated with a lever. This improvement has been followed by the invention of the Hoskins Deflector. This latter is a flexible semi-ball joint between the end of the discharge pipe and the nozzle. It is operated by a lever.

In 1852 and 1853 placer-mining was at the height of its prosperity. Labor was well paid, and employment was easily obtained by all who sought it. At this period

there still remained a few of the rich surface deposits which had formerly been so numerous.

First Drift-Mining.—The first extensive drift-mining in the old river channels was commenced in 1852 at Forest Hill, Placer County; though in 1851 a surface claim at Brown's Bar, on the Middle Fork of the American River, was drifted out by Joseph McGillivray.

In 1854, in consequence of the reported discovery of gold-diggings in Kern County, California, numbers of miners flocked to the southern part of the State, only to find there poor deposits of a very limited area.

Table Mountain.—Some miners engaged in sinking a shaft near Jamestown, Tuolumne County, where the gravel had been washed away, discovered gold at Table Mountain. Simultaneously other miners traced a seam of gravel containing gold along its sides, and it was found that this seam ran into a deep, rocky channel lying under the mountain. The presence of water in great quantity frustrated all attempts to work this deposit.

Deep Tunnels.—Further explorations developed the existence of channels running under this ridge, which were found to have a westerly course and to pitch deeper as work advanced. After several ineffectual attempts to drain the deposit, the gravel, which proved later to be exceedingly rich, was finally bottomed by a deep tunnel. "Ten square feet, superficial measurement, yielded $100,000, and a pint of gravel not unfrequently contained a pound of gold." *

An impetus to deep gravel mining or drifting was given by these developments, and extensive explorations of a similar character were undertaken subsequently in other parts of the State.

During the years 1856 and 1857 river, bar, and gulch mining were less productive, but quartz and ditch interests became more valuable.

The Frazer River excitement of 1853 caused a stam-

* See Ross Browne, "Reports on the Mineral Resources of the United States," 1867.

pede of miners and speculators to British Columbia. The subsequent developments of these gravel fields occasioned loss to those who had been attracted thither by the desire of gain.

In 1859–60 came the exodus to the Comstock, and in 1862 the rush to Idaho followed.

Hydraulic mining gained ground steadily from 1852 to 1865. As the river bars and surface diggings one after another were exhausted, the working of the old river deposits by the hydraulic process became a necessity. At the present time it is by this modern method of mining that the bulk of the gold of this State is produced, and in this business nearly $100,000,000 of capital are invested.

The hydraulic process is now carried on upon such a gigantic scale and to so vast an extent as to require the assistance of the science of hydraulics and engineering. Heretofore, apart from the construction of ditches and tunnels necessary for washing the gold-bearing dirt, engineers have had but little to do with the management of hydraulic claims.

The primitive placer-mining of 1852 to 1865 has passed into history. Forty-inch wrought-iron pipes have been substituted for canvas hose and stove-pipe, and with the replacing of one-inch streams by a mass of water discharged through nine-inch nozzles under 450-foot pressure the last remnants of the early methods disappeared.

CHAPTER III.

GENERAL TOPOGRAPHY AND GEOLOGY OF CALIFORNIA.*

THE topographical features of central California, as demonstrated by the explorations of the State Geological Survey, are found to be exceedingly simple. Four equi-distant parallel lines can be used in conveying a general idea of the physical geography of the State.

The Three great Belts of California.—A "main axial line," whose course would be N. 31° W., passing through the culminating peaks of the Sierra Nevada for a distance of nearly five hundred miles, can be assumed as the eastern boundary of the gold region. A second parallel, drawn fifty miles west of the "main axial line," will skirt the west base of the Sierra Nevada, along the edge of the foot-hills, from Red Bluff to Visalia. A third parallel, run equi-distant from the second, will follow very closely the eastern edge of the Coast Ranges from the neighborhood of Clear Lake to that of Kern Lake, a distance of over three hundred miles. A fourth equi-distant parallel will represent, as nearly as possible, the coast line of the Pacific, the western base of the Coast Ranges. These parallels divide the central portion of the State between Red Bluff (about lat. 40° N.) and Fort Tejon (about lat. 35° N.) into three belts—viz., the Sierra, the Great Valley of California, and the Coast Ranges.

This arrangement of the physical features holds good for a length of four hundred miles in the direction of the "main axial line." This division of California is the largest and by far the most important, embracing almost

* See vol. i., "Geological Survey of California," and Whitney's "Auriferous Gravels of the Sierra Nevada of California," which are the principal authorities for this chapter.

the whole of the agricultural and the greater part of the mining districts.

These lines divide the State geologically as well as physically. The Great Valley is the belt of recent alluvial deposits; the Sierra is the belt of intrusive granite, of strata principally of triassic and jurassic age, with important pliocene river deposits, of ante-cretaceous elevation, and of metamorphism induced by heat and pressure and resulting in a hard and crystalline condition of the rocks; the Coast Ranges form the belt of strata chiefly of cretaceous and tertiary age, of post-cretaceous elevation and of chemical metamorphism.

The Sierra is the belt of the precious metal, with some iron and copper; the Coast Ranges, principally of quicksilver and carbonaceous materials. The Sierra is the region of lofty heights, the Coast Ranges of moderate elevations, and the Great Valley of nearly dead level.

In the Sierra volcanic activity has ceased, but in the Coast Ranges solfataric action is still apparent.

This parallelism does not exist in the northern and southern parts of California. North of lat. 40° N. the Sierra and Coast Ranges approach one another and finally connect, the distinction between them being not yet definitely settled. In the south the Sierra swings to the west and joins, physically at least, with the Coast Ranges, which here, following the coast line, trend to the east. Thus the Great Valley is closed in its upper and lower extremities. The northern and the southern portions of the State have not been thoroughly examined, and the present knowledge of their topography and geology is very limited.

The map accompanying this work shows the mountain ranges where the auriferous gravels exist and also the streams draining the hydraulic mining districts.*

* The map was compiled from the latest official surveys by William Hammond Hall, State Engineer of California. For the purposes of this work certain additions have been made by the author.

THE BELT OF THE COAST RANGES.

Topographical Limits.—Exactly where the Coast Ranges begin and where they end is still an open question, and to decide this point satisfactorily more geological research is required. For the present general purpose, and until more exact data are furnished, it may be assumed that the belt of the Coast Ranges commences on the north at, or about, the mouth of the Klamath River. Its easterly boundary will run southeasterly to the head of the Sacramento valley, in the neighborhood of Shasta, and thence continue to Fort Tejon. From this point it passes to the east of the San Gabriel range, through Cajon Pass, to the east of the Temescal range and to the south of the Sierra de Santa Ana, striking the ocean in the vicinity of San Luis Rey, or perhaps including a narrow strip of territory along the shore south to the Mexican boundary.

Mountain System.—In this belt the mountains are not grouped in any one dominant range, but form numerous chains, much broken, and often running into one another, and all nearly parallel with the coast lines. These chains are separated by more or less distinct valleys, the system being broken through completely in only one place—namely, where the united waters of the Sacramento and San Joaquin rivers, which drain an area of fifty-seven thousand two hundred square miles, escape through Suisun, San Pablo, and San Francisco bays and the Golden Gate.

Compared with the Sierra Nevada, the Coast Ranges attain but inferior elevations. The dominant peaks of the several chains vary in height from thirty-five hundred to six thousand feet, few exceeding this limit. In the Sierra, on the other hand, there are numerous points over fourteen thousand feet above sea level, and for a large part of the range the passes have an elevation of more than nine thousand feet.

General Topographical Structure.—In the extreme northwestern part of the State the general structure of the Sierra Nevada prevails—an axial mass of granite associated with hard, crystalline rocks forming a high range. Coming south, and into the northern part of the Coast Range belt (west of Trinity and Klamath rivers), the structure is modified, the granite disappears, the old crystalline rocks are replaced by newer and softer strata, the elevations decrease, and the ranges become more numerous and indistinct, although as far as Clear Lake there is still one dominating range, quite well defined and parallel with the coast line.

South of Clear Lake the ranges are very much intermixed, the hills are lower and more rolling, and the valleys are wider. The average elevation decreases steadily to the vicinity of San Francisco Bay, the point of maximum depression.

Further south, to the bay of Monterey, there are two distinct ranges, that of Mount Diablo on the east and the Santa Cruz mountains on the west, with the southern part of the bay of San Francisco and the important valley of Santa Clara between.

South of the bay of Monterey, as far as San Luis Obispo County, the country becomes more mountainous and confused. The general elevation increases and the valleys become narrow and small. There can be distinguished, however, three equally plain systems: the continuation of the Mount Diablo range, east of the San Benito River; the Gavilan range (connecting with the last at its southern extremity), between the San Benito and Salinas rivers; and the Palo Escrito hills and Santa Lucia range on the west.

From the northern boundary of the belt to the south of this region the ranges have, in general, a sufficiently well marked northwest and southeast direction, as seen by the courses of the principal streams. Here, however, a change occurs, the coast line, and with it the mountain

chains, making a sudden turn nearly east and west, or almost at a right angle. The Sierra Nevada also bends around towards the west and meets the Coast Ranges, and hence results a confusion of topographical structure and of géological formation. The highest elevation of the belt, that of Mount San Antonio in the San Gabriel range, is here attained.

South of Los Angeles the coast line returns nearly to its former northwest and southeast course, and the ranges appear to come into general conformity with it; but there is apparently much irregularity in the details, of which, in fact, but little information is extant.

General Geological Structure.—As a general rule the rocks of the belt of the Coast Ranges are altered and unaltered sandstones, shales and slates of cretaceous and tertiary formations, with more or less limestone. The sedimentary beds have been metamorphosed over wide areas, crushed and folded to form the various ranges. In some regions volcanic rocks appear in large quantities. Granite occurs here and there, but almost always in small masses, except where the Sierra Nevada makes its influence felt. It forms an important feature, however, in some of the chains south of Monterey Bay, and forms the axis of the Santa Monica range, which differs in this respect from the other Coast Ranges. Other rocks are almost unknown, except where the Coast Ranges and the Sierra come into close contact.

Metamorphism.—The metamorphism of the rocks is principally chemical, and is very prevalent throughout the belt, often to such an extent that it is extremely difficult, if not impossible, to distinguish between rocks of the most opposite nature, such as the eruptive and the sedimentary. Especially noticeable is the enormous extent of change of slates into serpentine, in connection with which broken jaspery rocks, also a product of the alteration of slates, very commonly occur. These combinations of serpentines and jaspers are important to the

miner, as being the carriers of the quicksilver ores so extensively worked.

Cretaceous Formations.—The cretaceous formations are geologically very important, especially from a mining point of view. In the sandstones of the upper part of this formation occur all the workable beds of coal yet discovered.

Coal and Cinnabar Deposits.—Cinnabar deposits have been found in California in many localities and in rocks of nearly every age—in the Sierra Nevada and in the southern part of the State, in the triassic strata; in the Coast Ranges, also in the tertiary. But, so far as known, no valuable bodies of this mineral have been met with, except in the cretaceous, in which position it is known, in small quantities at least, in very numerous places, extending in a line with the metamorphic cretaceous from across the Oregon line in the north to the vicinity of Santa Barbara in the south.

The cretaceous formation, principally slates, jaspers, serpentine, and coarse sandstones, is almost the exclusive one north of Clear Lake; and south from there to San Francisco, in which region limestone occurs quite frequently, it still predominates. South of San Francisco Bay it forms the central and prevailing mass of the Mount Diablo range, extending as far as the north end of Tulare Lake, and gradually yielding to the tertiary. It also constitutes the crest and eastern side of the Santa Cruz range. In both these chains the cretaceous rocks are chiefly slates and sandstones, often highly altered, with limestone in smaller amounts; and serpentine and jaspers, "which have been traced unmistakably to their origin as cretaceous shales," are abundant. South of Tulare Lake the cretaceous formation is local and comparatively unimportant.

Tertiary Strata.—The tertiary strata are principally miocene, of marine origin, and for the most part are not much metamorphosed. They are hardly known north of

Clear Lake, although the great bituminous slate formation has been traced from Cape Mendocino through the country south to Los Angeles.

South of the bay of San Francisco the strata of this slate formation are everywhere turned up at a high angle, while north of the bay they are less disturbed. The tertiary, which is so limited north of San Francisco Bay, increases in importance going south. It flanks the cretaceous on both sides of the Mount Diablo range, and gradually limits it. The western and larger portion of the Santa Cruz range (the geology of which is somewhat complicated by the presence of intrusive granite rocks in various places) is said to be miocene. In the Gavilan and Santa Lucia system of ranges the tertiary is continued, and granite and highly metamorphosed rocks occur in considerable quantity; but the region is dry and very rough, and has been but little explored.

Asphaltum Deposits. — The different ranges in Santa Barbara and Ventura counties are made up chiefly of miocene rocks, consisting principally of a coarse-grained sandstone below, and over this a fine-grained slate or shale, often highly bituminous and generally very much contorted and tilted nearly vertical. In Santa Barbara, Ventura, and Los Angeles counties, where the tertiary bituminous slate predominates, the principal deposits of superficial asphaltum have been found, and here attempts have been made to strike flowing petroleum wells.

As one approaches the Sierra Nevada to the east of this region, and also in going south, granite becomes more frequent and the sedimentary rocks get harder and more crystalline. There is a granitic belt forming a continuation of the San Gabriel range, and connecting at Tejon Pass with the metamorphic and granitic masses of the Sierra, the crystalline rocks being apparently continuous, but the disturbance of the tertiary and cretaceous formations not being visible east of Tejon Pass. The granite forming the divide between the branches of the

Santa Clara River and the Mojave Desert is overlaid on the edge next the plain with stratified beds of recent volcanic material.

Tin Ore.—South of Los Angeles the ranges are of mixed character, and are very often considered as not belonging to the Coast Ranges proper. The Sierra de Santa Ana is composed on the south of granite, trappean and metamorphic rocks, while on the north coarse miocene sandstone and conglomerates prevail. The Temescal range consists principally of granite, porphyry, and metamorphic sandstone, partly cretaceous and partly tertiary. Here is the only known locality on the coast north of Mexico where tin ore has been found.

Still further south toward the Mexican boundary there is, along the ocean shore, a narrow strip of unaltered cretaceous and tertiary rocks.

Pliocene Gravels.—Pliocene gravels occur in various places in the Coast Ranges, sometimes in large deposits. These are in many cases the work of disintegrating adjacent formations. Gold has been found in some places, but seldom in paying quantities.

North of Clear Lake, at the bottom of the cañons which have been cut out chiefly by running water, are sometimes small deposits of gravel of pliocene age. These, especially at the north, carry gold. Between Clear Lake and San Francisco the only large gravel bed is the extensive one east of, and not far from, Clear Lake. This bed is covered in part by lava.

There are several localities in which deposits of gravel, probably pliocene, occur in the miocene strata of the Mount Diablo range, as south of the Livermore valley, but these contain no gold so far as known. Similar deposits are also found on the eastern edge of the Santa Cruz range, as on the east slope of the Mount Bache ridge, where considerable ground has been washed for gold, but without profit. Between the Gavilan and Mount Diablo ranges, south of Tres Pinos, there is an

immense mass of pliocene gravel, apparently non-auriferous, made up of pebbles of granite, red and green jaspers, silicious slates, and other metamorphic material. In the Santa Lucia range, near the Mission San Antonio, placers have been worked to some extent, and gold has been found in small quantities in several places.

The miocene strata of the ranges in Santa Barbara and Ventura counties are covered unconformably in places by nearly horizontal and slightly disturbed pliocene beds. In various places south of the junction, near Fort Tejon, of the Sierra Nevada and Coast Ranges, pliocene gravels occur over small areas. At San Francisco cañon these gravels have been washed and more or less gold obtained at various times since 1841 according to some authorities, and since 1838 according to Father Venegas.

Along the San Gabriel range gold-washing has been carried on intermittently with more or less profit. At the base of the Sierra de Santa Ana are immense accumulations of gravel made up of the wash of disintegrated tertiary strata.

Gold, Silver, and Copper Veins.—Veins of gold, silver, and copper have been reported at different localities along the Coast Ranges.

Eruptive Rocks.—A belt of eruptive rocks, of which Mount St. Helena is the culminating point, extends from near Napa to Clear Lake down to Suisun Bay, and large areas in this region are covered by lava, obsidian, pumice, and volcanic ashes. Especially in the vicinity of Clear Lake modern volcanic formations abound, and hot springs, sulphur beds, and other evidences of modern igneous action are common; but to the north of Clear Lake no volcanic phenomena of the kind are known, and south of San Francisco volcanic rocks are not found in any large quantities. Hot and sulphur springs are, however, quite common in the Coast Ranges.

THE GREAT VALLEY OF CALIFORNIA.

General Topography.—The valleys of the Sacramento and the San Joaquin rivers form in the centre of California a large plain, nearly elliptical in shape, extending from near Shasta, in lat. 40° 40′ N., to Fort Tejon, in lat. 34° 50′ N., an extreme length of four hundred and fifty miles, with an average width of forty miles, and an area of eighteen thousand square miles.

This plain is comparatively level. The Sacramento River, between Shasta and its mouth, has an average fall of 2.8 feet per mile. The San Joaquin River, from Kern Lake to its outlet, has an average inclination of 1.1 feet per mile. The valley of the Sacramento is narrower than that of the San Joaquin. The southern portion of the latter is very level and contains several shallow lakes of considerable area. The evaporation here about equals the water supply.

Drainage.—By far the larger part of the water coming into the Great Valley is derived from the Sierra Nevada. There is hardly a stream which furnishes water throughout the year on the east slope of the Coast Ranges, certainly not one in the San Joaquin division. The fact that many rivers, passing chiefly through the mining regions, flow down the west slope of the Sierra and empty into the Sacramento or San Joaquin, makes the whole drainage system worthy of attention.

Rainfall.—The rainfall of the Great Valley is comparatively small, especially in the southern parts. On the east slope of the Coast Ranges the amount of water derived from rain is small. On the west slope of the Sierra there is considerable precipitation, chiefly in winter, and in great part in the shape of snow. In the spring and early summer the flow of water down the last mentioned slope is greater than at other seasons, so much so that every year freshets occur. Heavy storms often cause destructive floods here, and if the theories of many

who have written on the subject of forests are correct, these floods will increase in magnitude with the destruction of timber in the Sierra.

THE BELT OF THE SIERRA NEVADA.

Topographical Structure.—The Sierra Nevada is a well-defined range of mountains situated on the edge of a high plateau, its eastern base being about four thousand feet high, while its western side slopes nearly to the sea-level. Its eastern flank is comparatively short and steep; its western, long and with a gradual descent, averaging in the central part of the State about one hundred feet per mile. This west side is broken by steep cañons in which the present rivers flow, running at about right angles with the axis of the ridge, so that an elevation of three thousand to four thousand feet above the sea-level the divide between any two streams is from several hundred to two thousand feet, or more, above the bottoms of the cañons on either side.

In the northern part of the State the range is outlined indistinctly, consisting of broken ridges with several prominent peaks. The general elevation may be assumed to be seven thousand or eight thousand feet. Mount Shasta, the highest point of this section, rises to a height of fourteen thousand four hundred and forty feet, dominating over all the others. South of this, from Lassen's Peak (lat. 40° 40′ N.) to near Tejon Pass (lat. 35° N.), the Sierra Nevada forms one clearly defined crest, gradually increasing in height toward the south. Along the head-waters of the Feather River, in Plumas and Sierra counties, the elevation of the prominent peaks is about nine thousand feet, and of the passes from five thousand to six thousand feet. Lassen's Peak rises ten thousand five hundred feet above the sea-level. The western slope here has a total width of some eighty-five miles.

Around the head-waters of the American River, in Nevada, Placer, and El Dorado counties, the main crest is

a little over nine thousand feet high, and the passes seven thousand to eight thousand feet; Donner Pass, through which the Central Pacific Railroad is built, being seven thousand feet high. The range here divides into two crests between which lies Lake Tahoe, a body of water twenty miles long, eight to twelve miles wide, and a little over six thousand feet above sea-level.

At the head-waters of the Merced and Tuolumne rivers, in Tuolumne and Mariposa counties, the main peaks are twelve thousand to thirteen thousand feet high, and the passes nine thousand to ten thousand feet. The width of the western slope is fully eighty miles.

The highest Sierra is between lat. 37° 31′ N. and lat. 36° N., in the region of the head-waters of the Kern, King's, and San Joaquin rivers. Here the main crest is twelve thousand to thirteen thousand feet high, with numerous points exceeding fourteen thousand feet, Mount Whitney being the culminating peak. The west slope is some fifty miles wide, with an average descent of two hundred and fifty feet to the mile.

Still further south the range turns to the west, and from this point is less marked in its character. In the southern part of the State is a mass of high, broken ranges (the San Bernardino range being the most extensive) allied in their general structure and formation to the main Sierra Nevada, but as yet insufficiently explored.

General Geological Structure.—The Sierra Nevada is made up of:

(1) a central intrusive core of granite, flanked by

(2) metamorphic slates of triassic and jurassic age (the so-called auriferous slate formation), over which lies

(3) a covering of cretaceous, tertiary, and post-tertiary deposits, which are either

(*a*) the river deposits which form the material which is washed, either by hydraulic or drift process, to extract the gold contained therein; or

(*b*) sedimentary volcanic layers; or
(*c*) lava; or finally, in some places,
(*d*) marine formations.

Granite.—The granite occurs in the extreme northwestern part of the State, disappearing in the northeastern under the extensive lava beds, reappearing in Butte and Plumas counties, and continuing to increase in amount of exposure toward the south, until in Fresno and Tulare counties it forms territorially by far the greater part of the belt, extending from the crest almost down to the plain.

Auriferous Slate Formation.—The auriferous slate formation, consisting chiefly of metamorphic, crystalline, argillaceous, chloritic and talcose slates, appears with, but subordinate to, the granite in the northwest. It appears again in Plumas and Butte counties, increasing in importance as the overlying lava decreases. North of the American River it occupies nearly the whole width of the western slope of the Sierra, with occasional areas of granite enclosed in it. Going south, it gradually contracts in width, being of but little importance south of Mariposa County. In the extreme south, at the junction of the Sierra and the Coast Ranges, it reappears and continues in San Bernardino and San Diego counties in connection with the granite.

The strata of this formation are elevated very considerably, often in a nearly vertical position. Speaking in very general terms, it may be said that the strike of the slates is usually parallel with the axis of the range and the dip in the southern portion of the belt is generally to the east.

Gold Quartz Veins.—In this formation occur almost exclusively the veins of quartz which carry gold in amounts which pay for working. While such veins occur also in the granite, and likewise, as has been mentioned, in some of the Coast Range formations, the paying gold quartz is rarely found outside of the auriferous slate formation. Some of these veins are of very great size,

notably the "great quartz vein," which has been traced from near the centre of Amador County through Calaveras and Tuolumne into Mariposa to the Mariposa Estate, a distance of eighty miles. The vein attains a width, in places, of several hundred feet.

Carboniferous Limestones.—There are certain limestones in Shasta and Butte counties which are carboniferous, the oldest formation known in the State, and which are possibly the same as those found here and there throughout the gold-mining region.

Marine Sedimentary Deposits.—The marine sedimentary deposits of cretaceous and tertiary age occur in the foothills all along the eastern margin of the Great Valley, lying unconformably on the upturned edges of the auriferous slates. Their greatest development is in Kern County, between Kern and White rivers. The rock is for the most part a soft sandstone, made up chiefly of granite débris.

Lava.—The chief lava country is in Plumas and Butte and the region north of these counties, and east of Trinity and Klamath rivers. Here is a series of volcanic cones, of which Lassen's Peak and Mount Shasta are the most prominent, from which flowed, in the later tertiary or still more recent times, the streams of lava which now cover many thousands of square miles of northern California and southern Oregon. The limitation of the auriferous belt at the north, in Plumas and Butte counties, is due not to the thinning out of the gold-bearing formation, but to its being covered by this volcanic mass.

Along the crest of the Sierra, to the south, are numerous volcanic vents and here and there are areas of lava, but these are comparatively small.*

Sedimentary Volcanic Layers.—Very frequent, and associated with the gravel deposits, are the sedimentary volcanic layers, consisting of fragments of lava which

* As to the Tuolumne Table Mountain see J. Ross Browne, "Mineral Resources of the U. S.," 1867, page 25.

have been carried to a distance by water and deposited as breccia or conglomerate of volcanic ashes or lapilli. These layers stratified, often in alternation with gravel or clay, generally cover the gravel deposits.

Gravel Deposits.—The gravel deposits occur in every variety of texture, from very fine pipe clay, through sands and gravels, to rolled pebbles and boulders sometimes weighing tons. It is now generally accepted that they have been laid down by the action of a system of tertiary rivers, which had the same general course (nearly) as the present streams on the west slope of the Sierra, but whose channels were wider and slopes greater. The waters of these rivers, eroding the auriferous slates with the included quartz veins, concentrated the precious metals in deposits often three hundred and fifty to four hundred feet wide at the bottom and sometimes several thousand feet wide on top. Their depth now varies from a few inches to six or seven hundred feet. Volcanic eruptions have in places covered these deposits with lava and tufa hundreds of feet deep. Denudation and erosion ensued and the products of volcanic activity have sometimes been covered in turn with gold-bearing detritus. Quantities of fossil wood and numerous remains of land and water animals have been found in the deposits and are being constantly unearthed as the mines are being worked.*

The deep cañons of the rivers of the extreme northern counties, especially the Klamath and its branches, contain

* In reference to the occurrence of gold the following note, taken from the *Engineering and Mining Journal*, February 10, 1877, relative to the discovery of pay gold in the New South Wales coal measures, will be found interesting. Mr C. S. Wilkinson, F.R.S., writes from the Geological Survey Office, Geelong, under date of November 25, to the Mining Department, as follows:

"During my examination of the Tallawang Gold Field Reserve I observed the important fact that the gold found in tertiary alluvial deposits at the old Tallawang and Clough's Gully diggings has been chiefly derived from conglomerates in the coal measures. These conglomerates are associated with beds of sandstone and shales containing the fossil plant of our coal measures, the *glossopteris*. . . . This is the first time that gold has been noticed to occur in payable quantity in the coal measures in the colony, and it is not unworthy of remark that we here possess one of the most ancient alluvial deposits in the world."

large amounts of gravel which have been washed quite extensively. These gravels are, however, thought to be ordinary river deposits on a large scale. In the southern part of the State, in Santa Barbara and San Diego counties, gold-washing has been carried on to some extent, but under unfavorable conditions and apparently without much profit.

Deposits at La Grange. — The deposits at La Grange, Stanislaus County, in a distance of one and a half miles in a northerly and southerly direction, cross four distinct and widely varying formations (see annexed topographical and geological section), which, enumerated in accordance with their relative ages, are: argillaceous slates, occurring north of the Tuolumne River, probably jurassic; diorite; a thin stratum of basaltic tufa; and post-pliocene auriferous deposits of sand and gravel.

The slates have a general strike northwesterly and southeasterly, parallel to the general trend of the Sierra Nevada Mountains, and dip at an angle of about sixty degrees. The diorite is occasionally porphyritic, changing into aphanite and serpentine in places which, so far as observed, are not on the direct line of the section. It sometimes contains quartz, and must be classed as syenitic. Where overlaid by basaltic tufa or gravel it is very much decomposed, presenting the appearance of clay shale, showing thick-bedded stratification, a water-worn and undulating surface, with numerous pot-holes similar to a river bed.

The basaltic tufa, from two to six feet thick, occurs in more or less isolated patches, having been washed away in places and cut up by streams previous to or during the deposition of the gravel. It is generally of a light greenish or yellowish color, occasionally pink or of a rusty iron tinge, and frequently contains angular quartz pebbles and rounded masses of flint-like rock.

The auriferous deposits of sand and gravel rest upon the tufa, and are not capped by any volcanic flow. Bones

and teeth of the elephant have been found imbedded in them. The gravel is composed of such rocks only as are found to the eastward in the foothills and the mountains of the Sierra Nevada, and consequently must have come from that general direction.

A section of the gravel occurring in the New Kelly claim shows the deposit to consist of:

I.	Top soil (red sand)	1.7	feet.
II.	Coarse red gravel with sand (the gravel is chiefly granite)	6.1	"
III.	Red cement hard-pan	6.0	"
IV.	White sandy clay	0.8	"
V.	Red cement hard-pan	3.3	"
VI.	Sand and pebbles	6.5	"
VII.	Loose yellowish sand	7.4	"
VIII.	Dark-colored gravel of granite, slate, porphyry, greenstone, aphanite, serpentine, quartzite, diorite, etc.	13.2	"
	Total	45.0	"

Quartz gravel of large size is of rare occurrence. Boulders of diorite, several tons in weight, are common in some of the deeper holes of the bed-rock. The greater part of the gold is confined to the lower stratum of gravel, next to the bed-rock, and is associated with magnetic iron and platinum.

CHAPTER IV.

THE DISTRIBUTION OF GOLD IN DEPOSITS AND THE VALUE OF DIFFERENT STRATA.

No absolutely satisfactory explanation has yet been given of the distribution of gold in deposits.*

The opinion is held by some that the precious metal is uniformly disseminated throughout the beds. But this is the case only in very exceptional instances, and the unequal distribution of the gold † is so general as to have given rise in California to the expression "pay dirt," which means the stratum or strata containing gold in amounts which render work profitable.

Top Gravel sometimes pays.—In a few instances the gold occurs in comparatively large amounts in thin streaks of cemented gravel scattered here and there in the alluvions, and in some shallow banks ‡ it is quite generally disseminated. Even in high banks the upper portion or "top gravel," when consisting of fine light quartz-wash with no boulders or pipe-clay, and where the cost of hydraulicking is very small (owing to the facilities of a heavy grade, sufficient dump, and cheap water), has been washed at a profit, though carrying an insignificant amount of gold per cubic yard. For this reason the miner always tests the whole of the deposit.

* See "The Auriferous Gravels of the Sierra Nevada of California," p. 516. By J. D. Whitney.

† On the subject of the relative position of gold in deposits see Report of Mr. Stutchbury, Government Geologist of New South Wales; *Quarterly Jour. Geol. Soc.* 1858, p. 583, M. A. Selwin; "Gold-Fields and Mineral Districts of Victoria," pp. 81, 82, 87, 131, 173, R. Brough Smythe; Cotta's "Lehre v. d. Erzlagerstätten," vol. i. p. 101, and vol. ii. p. 556; Murchison's "Russia and the Ural Mts.," vol. i. pp. 482-487, and "Siluria," p. 456; Whitney's "Auriferous Gravels of the Sierra Nevada," p. 361; J. Grimm's "Lagerstätten d. Nutzbaren Mineralien," p. 26; Hartt's "Geol. and Phys. Geog. of Brazil," pp. 50, 51, 159, 160; Mawe's Travels, pp. 222-227; Munroe's "Mineral Wealth of Japan," Trans. Amer. Inst. of Mining Engineers, vol. v. p. 236; "Gold Deposits of Jaragua," *Ann. d. Mines*, 1817, vol. ii. p. 202.

‡ See "Gold-Fields and Mineral Districts of Victoria," p. 84.

The top gravel of the channel which passes through Columbia Hill, Nevada County, has in several instances been successfully washed. This is especially remarkable on account of the great depth of this deposit, which, from the explorations on Badger Hill and Grizzly Hill, is inferred to be from six hundred to six hundred and twenty feet deep.

Gold in the Grass-Roots.—Not unfrequently a fine lamina gold is found in the grass-roots. This last mentioned circumstance is in no way localized, the same fact having been noted in other countries. Mawe called attention to the existence of gold in the grass-roots on Mount San Antonio,* in Brazil; and Walsh states that gold was first discovered in the deposits between San José and San Joäo, Brazil, by Paulistas, who, pulling tufts of grass, "found numerous particles of gold entangled in the roots." †

Pay Gravel sometimes high above Bed-Rock.—At the Polar Star Mine, Indiana Hill, Placer County, the best pay was found from six to eighty feet above bed-rock. At diggings near Forest Hill, Placer County, the gravel twenty to sixty feet above the bed-rock has yielded profits. At Bath a stratum one hundred feet above bed-rock was drifted profitably and the top dirt hydraulicked subsequently.

Pay Gravel generally near Bed-Rock.—But experience has proved that, as an almost universal rule, the top gravel of deep alluvions is not rich enough to warrant large investments of capital. Also that the "pay" is obtained, not from the washings of the entire bank, but chiefly from that stratum or those strata which are in most cases within eight or ten feet of the bed-rock. Where this is of slate upturned on its edges the gold frequently permeates it one or two feet.‡

* Mawe's Travels, p. 264. † Walsh's "Notices of Brazil," 1828-29, vol. ii. p. 122.

‡ See Murchison's "Siluria," p. 456, and "Russia and the Ural Mountains," vol. i. p. 487; also "Gold-Fields and Mineral Districts of Victoria," pp. 86, 106.

Tuolumne River Claims. — The gold alluvions found near and along the banks of the Tuolumne River, Stanislaus County, present some striking examples of the distribution of the precious metal. The pay dirt in the Chesnau claim is confined to within six feet of the bed-rock. In the Sicard claim, six hundred feet south of the last and across a ravine, with banks twenty to forty feet high, the gold is disseminated more generally so long as there are no sand strata; but whenever the latter appear the pay is confined to near the bed-rock.

In the Patricksville Light claim the pay stratum is six or seven feet thick and adjoins the bed-rock. The gold is concentrated in this layer so long as there are sand strata in the bank, but with their disappearance it becomes more diffused throughout the detritus.

At the French Hill claim the pay was limited almost exclusively to the gravel near the bed-rock.

Nevada County.—The bulk of the pay dirt in the cement gravel in Nevada County is within thirty feet of the bottom. In drift claims the workings are nearly always confined to within a few feet of the bed of the channel.

Sand generally poorer than Gravel.—In the gold-bearing drift of the Sierra Nevada layers consisting exclusively of wash-sand are generally found to contain very little if any of the precious metal.

Rich Pay in Undulations and Depressions.—At French Hill, Stanislaus County, where the bed-rock was undulating, and in depressions found around a little hill formed by a sudden rise in the bed-rock, the gravel paid better than in any other portion of the claim.

The gold-fields south of Miask,* in the Ural Mountains, present a similar case, all the undulating ground and depressions around conical hills being the most productive of gold.

At the Patricksville Light claim a large hole in the

* "Russia and the Ural Mountains," vol. i. p. 488.

bed-rock, twenty-five feet deep, was bottomed. The hole was filled with gravel, but no pay was obtained. The pay stratum was found to be on a level with, and a continuation of, the pay stratum of the rest of the claim. On the other hand, at the Chesnau and French Hill claims whenever these hollows are found a large yield of gold is invariably obtained.

The experience of miners in the gold-fields of Victoria has led to the conclusion that "in large auriferous rivers gold is always found on the bars or points, and not in the deep pools or bends." In substantiation of this are cited Reid's Creek, Woolshed, Twist's Fall, Yackandanah near Osborne's Flat, and Rowdy Flat; at each of these places large holes were cleaned out and only a few colors obtained, while shallow flats immediately below them were very rich.*

In gulch-mining it sometimes happens that from the position of the bed-rock the detrital accumulations assume the form of reclining cones, the apex reposing upon the top of the hill. Where such is the case the bulk of the gold is concentrated in the lower end of the deposit. These gulches are frequently found to be exceedingly rich.

These facts are cited merely as an explanatory outline of the subject, and to show why a system of sluicing should be adopted which bottoms the entire deposit.

EXAMPLES OF THE COMPARATIVE VALUES OF THE DIFFERENT GRAVEL STRATA.

North Bloomfield.—To ascertain the comparative value of the gravel strata at Malakoff, Nevada County, on the ground of the North Bloomfield Mining Company, a series of tests was made of the dirt extracted from a shaft sunk, two hundred and seven feet deep, in the channel. The first one hundred and twenty feet from the surface

* "Gold-Fields and Mineral Districts of Victoria," p. 134.

contained a large number of very fine colors to the pan, but of inconsiderable weight. The gravel from the remaining eighty-seven feet, sunk to the bed-rock, contained coarser and heavier gold, the last eight feet averaging from 5 to 20 cents per pan. Drifts opened from the bottom of this shaft were systematically sampled and compared with equal quantities taken from the layers of the upper bank. The several samples aggregated two and a half tons, all of which were panned out carefully in two hundred and forty tests; and the results obtained showed that the blue or lower gravel stratum contained $1 50 per ton, while the white or upper gravel gave a large number of fine colors, but of insignificant weight.

From 1870 to 1874 the North Bloomfield Mining Company washed three and one-quarter million cubic yards of top gravel, which yielded only 2.9 cents per cubic yard and a gross profit of $2,232 84. In 1877 a rough estimate was made of the comparative yield of the upper and lower gravel washed during the year. The top gravel was assumed to be from a few feet to over two hundred feet deep, and the bottom gravel sixty-five feet deep.

The results obtained were that 1,591,730 cubic yards of top gravel yielded 3.8 cents per cubic yard, and 702,200 cubic yards of bottom gravel returned 32.9 cents per cubic yard.

Patricksville Light Claim.—To investigate more thoroughly the question a test of top and bottom gravel was made at the Light claim, Patricksville: 58,340 cubic yards of top gravel yielded $1,200, or 2 cents per cubic yard. The bottom gravel (four feet deep) was then washed, when it was discovered that two-thirds of this gravel had been drifted extensively; but notwithstanding this fact 4,966 cubic yards yielded $2,775 07, or 55 cents per cubic yard.

La Grange Light Claim.—A trial of top dirt was also made at the Light claim, La Grange: 41,038 cubic yards of top dirt yielded $1,500, or 3.7 cents per cubic

yard. The ground, in both of the last mentioned instances, was surveyed and the returns per cubic yard are as accurate as it is practicable to obtain.

Polar Star Mine.—In the appendix to the "Auriferous Gravels of the Sierra Nevada of California," Professor W. H. Pettee estimates the value of the top gravel at the Polar Star Mine to be about 11 cents per cubic yard, and at Quaker Hill the yield of the top gravel is supposed to approximate 6 cents per cubic yard. The yield of the bottom gravel, however, is not given, and the estimates of the upper gravel are approximates based on the statements of others, and not the results of accurate detailed surveys.

CHAPTER V.

AMOUNT OF WORKABLE GRAVEL REMAINING IN CALIFORNIA.

THE quantity of auriferous gravel remaining on the flanks of the Sierra Nevada is very great, but necessarily the amount available for hydraulic mining is limited.

Minimum Pay Yield.—The minimum yield per cubic yard of material which can be mined profitably, must be considered in determining the extent of workable deposits. This cannot be stated in advance without a knowledge, in any given case, of the other factors: as area of ground, character and depth of deposit, facilities for working and dump, supply and cost of water, price of labor and amount of capital invested. In certain localities, even under very disadvantageous circumstances, it has paid to work gravel yielding only four cents per cubic yard; and Mr. Skidmore states that, within his personal knowledge, a claim near Iowa Hill, Placer County, in 1879 paid "a fair profit" when the product was only three cents per cubic yard.

With an abundance of cheap water, four per cent. grades, good dump, banks of light gravel one hundred and fifty feet in height and over, a large area of ground, labor at one dollar per diem, and good management, the *total running* expenses ought not to exceed three cents per cubic yard at the present time, and with present methods. Therefore under these conditions gravel yielding more than three cents per yard ought to pay a greater or less rate of interest on the capital invested in the purchase of the claim and water rights, the building of necessary ditches, flumes, pipes, etc., and in the other appliances requisite for commencing active operations.

The reports of the State Engineer of California (1880) and of Lieut.-Col. Mendell, U. S. A. (1882), give the following data of the estimated amounts of workable gold deposits remaining along the rivers of the principal hydraulic region on the west flank of the Sierra Nevada in California:

	Cub. yds. of Gravel.
The Upper and Lower Feather, large amounts......	Unestimated.
The Yuba and its tributaries, about..................	700,000,000
The Bear " " "	50,000,000
The American " "	75,000,000
The Cosumnes, principally at Hill Top, from 11,000,000 to 12,000,000, say........................	11,500,000
The Mokelumne, enormous amounts, but not favorably situated..................................	Unestimated.
The Calaveras, upper portion......................	Unestimated.
" " lower portion, principally at Jenny Lind...	22,500,000
The Stanislaus....................................	Unestimated.
The Tuolumne, large amounts....................	Unestimated.

"The quantity of auriferous gravel now remaining on the flanks of the Sierra Nevada is practically unlimited. Only a comparatively small portion of the whole can be regarded as workable under existing conditions." *

Since Mr. Hague's report upon Eureka Lake property (1876), wherein it is stated that the quantity to be mined between the Yubas was 700,000,000 cubic yards (roughly estimated), explorations have proven that this estimate is too large. It is true that there was that quantity of gravel, and perhaps more, in that locality. But since then a quantity, possibly exceeding 100,000,000 yards, has been mined out, and the result of the work has proven that a portion of this gravel channel can never be mined profitably, for the reasons, 1st, that it is capped with lava and cannot be hydraulicked, and it will not pay to drift; and, 2d, another portion is so situated that it is impossible to drain it, or it is too far from the streams to dispose of the débris. It is now estimated that not more than 400,000,000 cubic yards of gravel remain here available for washing.

* Report on Mining Debris in Cal. Rivers, by Lieut.-Col. G. H. Mendell, U.S.A., p. 35.

CHAPTER VI.

THE DIFFERENT METHODS OF MINING GOLD-PLACERS.

THE gold alluvions occur in many different forms: in river channels, in basins and on flats, as surface deposits of sand and gravel, or as accumulations of detritus (consisting of clay, sand, gravel, pebbles, and boulders of all sizes) covered with varying thicknesses of lava and other volcanic products.

Miners' Classification of Deposits.—Miners classify the deposits in various ways, according to their mode of occurrence and topographical position, and according to the mining systems employed in working them. The term "shallow placers" is applied to deposits whose depth varies from a few inches to several feet, to distinguish them from "deep placers," which often cover large areas and have a depth varying from one hundred to several hundred feet.

"Hill Claims," or deposits of gravel on hills; "Bench Claims," or placers occurring in bench form on declivities and above the level of existing rivers; "Gulch Diggings," found in gulches and ravines; "Flat Deposits," on small plains or flats; "Bar Claims," or bars of sand and gravel on the sides of streams, generally above the water-level; and "Beach Sands," or the auriferous sands of the sea-shore, are terms in common use, as well as the names "sluice," "drift," and "hydraulic" diggings.

Classification of Mining Operations.—The mining methods in common use may be divided into two general classes—viz., Surface-Mining and Deep-Mining.

SURFACE-MINING.

This term may be applied to the operations on the shallow placers from which in early days large returns have been obtained, but which from their nature are of a transient character, and in California are no longer in use to any great extent.

Under this head will be treated the methods of Dry-Washing, Beach-Mining, River or Bar Mining, Ground-Sluicing, and Booming.

Dry-Washing.—Dry-washing was carried on in the early days, principally by Mexicans, in those localities where water could not be obtained. The Mexican method consisted in pulverizing selected rich dirt, thoroughly drying it, and then working it in a batea. The earthy portions, by a circular motion given to the disk, were separated from the gold, which remained behind. The gold was also extracted by winnowing. Of late years various machines have been invented and used from time to time, but necessarily their application is limited.

Beach-Mining.—In various places along the Pacific coast, principally between Cape Mendocino in California and the Umpqua River in Oregon, the beach sands have been found to contain gold and have been worked to a limited extent. The first discovery, which for a time caused great excitement, was made in 1850 at Gold Bluff, south of the mouth of the Klamath River.

The gold occurs in a finely divided state, in layers (sometimes one or two feet deep) of magnetic iron sand, which by the concentrating action of the waves and tide is separated from the lighter quartz sand. By the wash of the water the auriferous layers are sometimes exposed and sometimes covered by the non-auriferous material.

With the gold platinum is found. The fragments of the platinum are more compact and less flattened than the gold particles, which are of leaf-like form and of nearly the same diameter as the magnetic-iron grains, from which

they are separated only with difficulty by the present process of washing.

S. B. Christy found that the gold amalgamates easily, but that the finer particles, when once allowed to dry, seem to become covered with a film of air and to float readily on subsequent immersion in water.

Prof. J. D. Dana considers that these deposits date from the close of the Glacial, and partly from the latter half of the Champlain period.

As the tides continually alter the position of the exposed auriferous layers, it is necessary to prospect every day for the richest spots, which are generally covered at high water. At low tide the miners proceed to the localities selected, scrape up the thin gold-bearing strata, and transport the material to the washing place. The washing is generally done in sluices, to which are attached various gold-saving contrivances.

It is claimed that much of the sand assays from $10 to $30 per ton, and that very large amounts assay from $5 to $10, only a part of which, however, is saved. Skidmore states that the variable character of the sands prevents beach-mining enterprises from being carried on successfully for any length of time.

Bar and River Mining.—In early days river-mining was extensively carried on. The discovery of rich bars caused many excitements. It led to the rapid exploration and settlement of large areas of country, and was generally the first step towards opening up the gold-mining regions.

The portions of the bars above water-level being soon exhausted, the miners' attention was naturally led to the exploration of the parts under water. Streams were dammed and turned into new channels, often at enormous costs and risks. The beds of rivers for considerable distances were laid bare while the miner worked his claim. This class of mining, apart from the danger arising from floods and breaking of dams, had in it a factor of uncertainty—

namely, the value of the claim, which could only be ascertained after all the principal expenses had been incurred. The losses in many instances were very large, but in other cases the gains obtained in a short time were so enormous as to throw around this class of work a fascination which induced many to engage in it.

To obviate the necessity of turning the rivers out of their channels dredging machines have been built and used; and the plan of sinking shafts on the banks and tunnelling (drifting) under the surface of the bed has been suggested. Projects for working the river channels (always supposed to contain enormous stores of hidden wealth) are still proposed from time to time, but actual operations are not common.

Ground-Sluicing. — Ground-sluicing consists in treating the gold-bearing gravel, which is excavated by pick and shovel, by washing it in trenches cut in the bed-rock. It is similar to hydraulic mining, except that the water is not used under pressure and often no wooden sluices are used below the trenches, the rough natural rock serving for riffles. The lighter material is removed by means of the water, while the heavier dirt remaining behind is collected and worked in rockers. This process of gold-washing was carried on by the Romans in the early part of the Christian era.

Booming.—Booming is simply ground-sluicing on a large scale, the only difference being that instead of washing the gravel by means of a continuous stream of water, the contents of the entire reservoir are discharged at once and all the material which has been collected below it is swept into the sluices. The rush of the water carries off the boulders and dirt, leaving behind the heavy particles of gold and magnetic iron sands, which are collected on bed-rock floors. Booming has been extensively practised in California, Idaho, Montana, and Colorado. The requirements for this kind of gold-mining are a sufficiently large reservoir conveniently situated above the gravel de-

posit, and a dam for storing the water, so arranged that flood-gates can quickly discharge the entire contents of the reservoir without damage to the dam.

Pliny, in his "Natural History," speaking of gold-washing, says: "When they have reached the head of the fall, at the very brow of the mountain, reservoirs are hollowed out a couple of hundred feet in length and breadth, some ten feet in depth. In these reservoirs there are generally five sluices left, about three feet square, so that the moment the reservoir is filled the flood-gates are struck away, and the torrent bursts forth with such a degree of violence as to roll outward any fragments of rock which may obstruct its passage. When they have reached the level ground, too, there is still another labor that awaits them: trenches, known as 'agogæ,' have to be dug for the passage of the water, and these, at regular intervals, have a layer of silex placed at the bottom. This silex is a plant like the rosemary in appearance, rough and prickly, and well adapted for arresting any pieces of gold that may be carried along. The sides, too, are closed in with planks, and are supported by arches when carried over steep and precipitous spots. The earth, carried onwards by the stream, arrives at the sea at last, and thus is the shattered mountain washed away—causes which have greatly tended to extend the shores of Spain by these encroachments on the deep."

DEEP-MINING.

The two principal methods of Deep-Mining are Drifting and Hydraulicking.

Drifting.—Gold is often mined in deep deposits by means of tunnels and drifts. This is styled drift-mining, which, as a rule, is resorted to only in those districts where the deposits are covered by an overflow from volcanic sources, though in many instances the bottom stratum (sometimes intermediate strata) has been drifted out of banks not capped with lava.

Drifting presupposes the concentration of the precious metal in a well defined stratum or channel. This method has been extensively employed in many parts of California, particularly in Placer, Sierra, and Plumas counties.

Where a pay channel has been found, or is surmised to exist, a tunnel is driven to develop it. This tunnel must be run in such a manner as to drain all parts of the mine, and its location is therefore a matter of the greatest importance. Before commencing such a work, which may require years for its completion and cost large sums of money, every precaution should be taken to ascertain the exact position of the channel. Want of knowledge on this point has caused disastrous failures in but too many cases.

As the channel can often be found only by means of tunnels, the risk of undertaking drift-mining is apparent. In those fortunate instances in which the channel is disclosed on the surface and rises as it enters the hill, the tunnel is run along its bed, partially in the bed-rock. Otherwise the tunnel is driven below the channel or through the rim-rock, being located with such a grade that the deepest part of the workings will be above it.

In some claims shafts have been sunk and the gravel drifted out has been raised through these shafts to the surface. This method is quite common in Australia, but comparatively rare in California.

When a tunnel has been properly located and the channel opened, drifts are run through the pay ground on both sides and the material is breasted out regularly, timbering being employed as the work may require. Shafts must sometimes be raised to the surface for the sake of ventilation.

The gravel is removed through the tunnel by means of a tramway and carried to the mouth, where it is dumped on floors and then washed in the sluices. When too firmly cemented to be broken up by sluicing, the gravel is crushed under stamps.

One of the most noted drift-mines in the State is the Bald Mountain, Sierra County, where there is every facility for economical working. There steam locomotives are used for transporting men and material through the tunnel, which is over one and one-fourth miles long.

The following sketches of the workings of the Sunny South Mine, in Placer County, will give a general idea of the method of drift-mining. At this place the main tunnel is below the channel, allowing the mine to be opened and worked in a very convenient manner.

Drifting was at one time the most extensively used method of deep mining, and through it a very large amount of information has been obtained as to the nature of the ancient river channels.

Hydraulic Mining.—Hydraulic mining is that method of gold-mining in which the ground is excavated by means of water discharged against it under pressure (hydraulicked).

The term in its limited sense, as generally applied, presupposes the existence of, 1st, water, in sufficient quantity, which can be used under pressure for mining; 2d, gravel deposits containing gold which can be worked profitably by the application of water in the manner above mentioned.

Origin in California. — The application of the science of hydraulics to the mining of auriferous gravels originated in California. The pressing necessity of a more economical process of gold-washing became evident as the rich surface deposits were exhausted, and led to the adoption of this method, which was favored by the topography of the country.

Hydraulic vs. Drift Mining.—Deep placers, if sufficiently rich, can be, and for various reasons generally are, worked by drifting. But the results of actual practice in Nevada County and elsewhere demonstrate that hydraulic mining, compared with drifting, employs twice

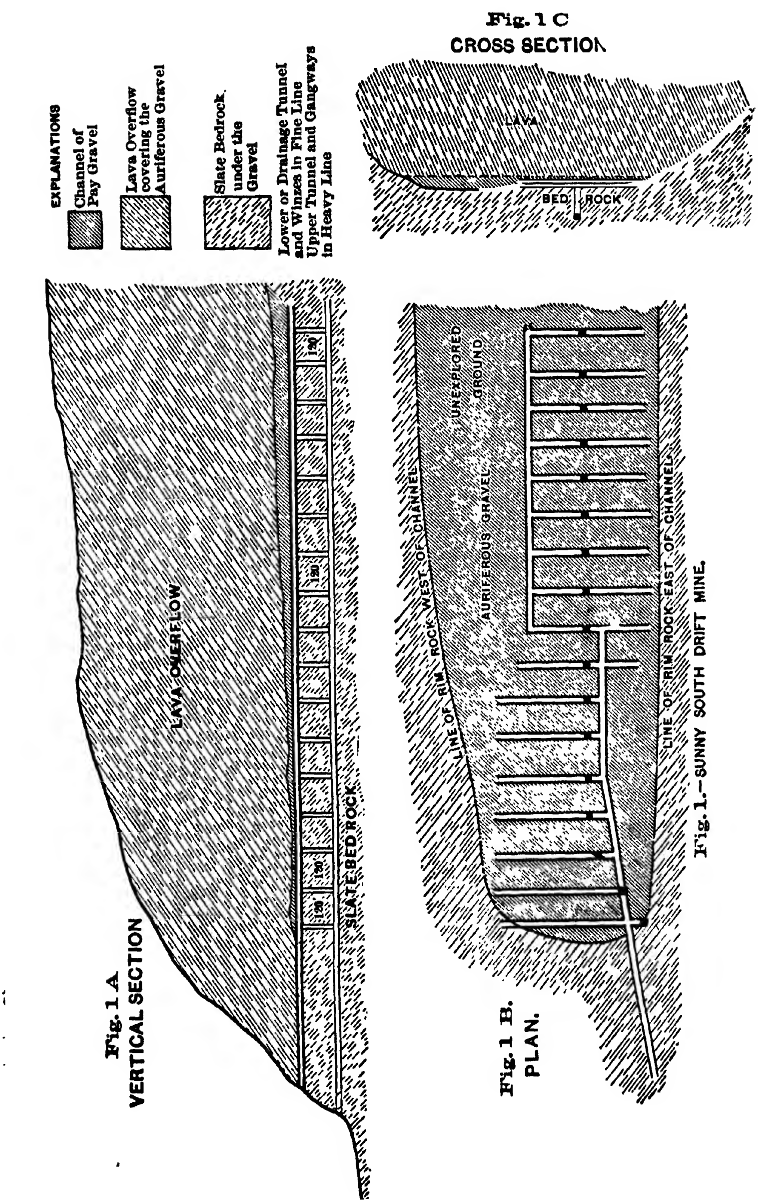


Fig. 1.—SUNNY SOUTH DRIFT MINE.

California as they are generally found to be in the Ural Mountains.

A black sand, composed chiefly of glancing grains of magnetic iron, generally accompanies the precious metal, though it occurs also without it.

Dr. T. Sterry Hunt, speaking of the impressions which prevail in reference to the presence of black sand in auriferous alluvions, very appropriately remarks that "similar black sand residues, consisting chiefly of various ores of iron (sometimes oxide of tin and other minerals), may be obtained from the washing of almost all sands and gravels derived from crystalline rocks, and the occurrence of a black sand, therefore, in no way indicates the presence of gold. When, however, this metal is present in gravel, it, from its great weight, remains behind with the black sand and dense matters in the residue after washing." *

Explorations at Malakoff.—The explorations of the North Bloomfield Company furnish a remarkable instance of the extent to which preliminary work has been successfully carried on. To determine the value of their claims and the feasibility of working them, four prospect shafts were sunk to ascertain the value of the gravel, the position of the channel, and the depth to the bed-rock. No. 1 shaft struck the bed-rock of the main channel at a depth of two hundred and seven feet, one hundred and thirty-five feet of which was in blue gravel averaging 41 cents per cubic yard. Drifts were driven from the bottom of this shaft a distance of twelve hundred feet on the course of the channel, the width of which was estimated at five hundred feet. The aggregate length of the channel explorations was over two thousand feet. The samples of the various drifts indicated a value of $2.01 per cubic yard. The actual yield of 21,614 tons of gravel extracted from these drifts was $33,053.69, or $1.53 per ton, or about $2.75 per cubic yard.

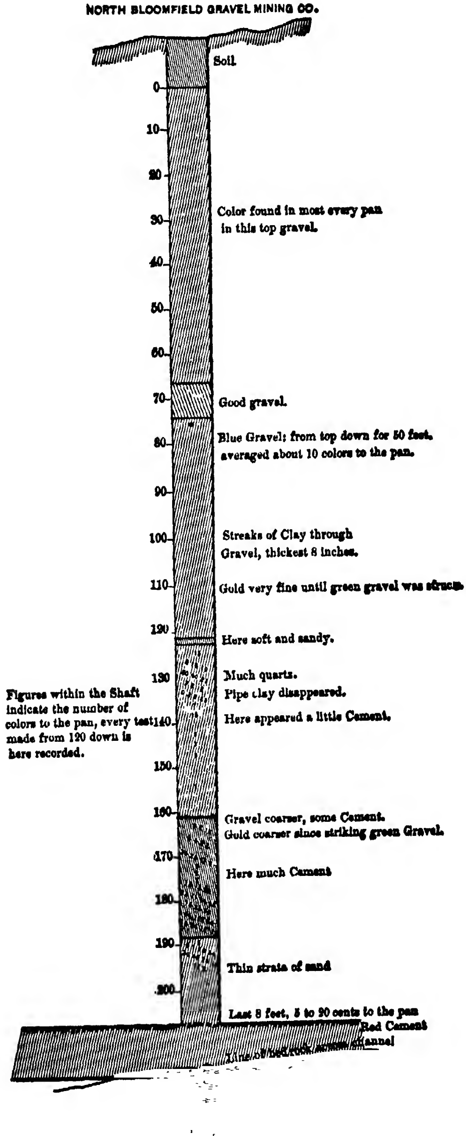
The gross cost of the entire prospecting work, including the four shafts, was $63,956.20.

* "Geological Survey of Canada, Report of Progress, 1863–66," p. 26

SECTION OF SHAFT NO. 1.

MALAKOFF

NORTH BLOOMFIELD GRAVEL MINING CO.



CHAPTER VIII.

RESERVOIRS AND DAMS.

STORAGE RESERVOIRS.

Sources of Water-Supply.—Running streams, melting snows and rains are the sources from which the mining districts derive their water-supply. The altitudes of the gravel deposits, two hundred to fifty-five hundred feet above the sea-level, necessitate the bringing of the water from still greater elevations nearer the sources of the streams. The supply from these streams is not always sufficient. Towards the end of winter and during the spring months, while the mountains are still covered with deep snow, rains and temperate weather cause sudden and rapid thawing, and enormous volumes of water are then discharged from the many water-sheds on the west flank of the Sierra Nevada into the Great Valley of California, and freshets are of quite common occurrence. To make this supply of water available, storage reservoirs have been constructed by some of the large hydraulic-mining companies.

The dry season in California is from May to November, but the streams do not run dry until the middle of June or July.

Requirements for Sites.—The principal storage reservoirs in the State are situated at elevations of five thousand to seven thousand feet above the sea-level. The location of a proper site for a storage reservoir is of paramount importance. In selecting a site especial attention must be paid to the following points:

(1) A proper elevation.

(2) The water-supply from all creeks and springs, and the catchment area.

(3) The amount of rain and snowfall.

(4) The formation and character of the ground, with especial reference to the amount of absorption and evaporation.

All of these points must be thoroughly investigated and determined. It is supposed that the catchment area has been ascertained, and that it is sufficiently large for its minimum discharge to supply all requirements.

Elevation.—The elevation of a reservoir depends upon the location of the mines and the altitude and extent of the country which it is proposed to cover with the ditch. The reservoir should be located below the snow belt wherever possible, and so situated as to obtain the largest water-supply from the catchment area.

Streams.—All the streams should be gauged carefully to determine the minimum and the average supply.

Rainfall.—In new and unexplored localities the water-supply due to rainfall can be determined only by actual measurement. It cannot be too earnestly impressed upon the engineer that for all such information he must depend on his own observations, which in some cases may require a prolonged stay of a season or more in the field. Under any circumstances rainfall data cannot be relied upon, unless based on many decades of observation.

The rainfall is always greater in mountain districts than in the lowlands. It is greatest on the slopes facing the direction from which the moist winds blow. Definite data of the rainfall of any catchment area can be obtained only by establishing rain gauges at different points, where the observations should be made daily during the season.

Snowfall.—The measurement of the snowfall must be taken on a level, and a given amount of snow reduced to water and calculated for rain.

Absorption and Evaporation.—In reference to the ground, the most desirable formation is that of com-

pact rocks, like granite, gneiss, or slates. Localities where the formation consists of porous rocks, sandstones or limestones, are not desirable on account of the great loss from absorption.

Steep and denuded slopes are always the best, as but little water will escape. The greatest slope will give the largest available quantity of water. The configuration of the ground influences and affects evaporation, and vegetation causes a large amount of absorption. The losses due to absorption and evaporation are reduced to a minimum where the site of a reservoir is in a compact formation with steep sides, and the surface area is consequently small. Evaporation varies with the season of the year and the weather (being most active in summer), while percolation, depending on the soil, varies from year to year. Percolation is greatest during melting of snows, and especially when a thaw follows small falls of snow. From reliable experiments made in France and England, the ratio of evaporation to rainfall was determined (1839 to 1852) in the former to have been 76.57 per cent., and in the latter, subsequently, 77.27 per cent.*

Finally, it must be added that the rule for estimating the total quantity available for storage varies in different districts. In some localities two-thirds of the total amount is estimated to be serviceable, and in others one-third. At the Bowman reservoir 75 per cent. of the total rainfall and snowfall, reduced to rain, is stored.

Reservoir Gauge.—In the construction of reservoirs the location selected must be sufficiently large to hold a supply necessary to meet a maximum demand. The exact area of the reservoir should be determined, and a table showing its contents for every foot of depth made, so that, from an inspection of the gauge and reference to the table, the amount of water available for service can always be known. A longitudinal section through the centre of the reservoir, with cross-sections and contour lines, five

* Harcourt, "Rivers and Canals," p. 3.

feet above each other vertically, will enable the engineer to determine the height of the dam and to ascertain the contents of the reservoir with the water at any depth.

Reservoir Statistics.—On the head-waters of one of the branches of the Yuba River in Nevada County, at an elevation of fifty-three hundred feet above sea-level, the North Bloomfield Company has established a complete system of reservoirs for the storage of water. Their Bowman reservoir and the small ones above it contain about 1,050,000,000 cubic feet of water. The catchment area is 28.94 square miles. The cost of the reservoirs and dams to date is $246,707.51, including the cost of distributing reservoirs.

The Rudyard or English reservoir of the Milton Company since its enlargement contains 650,000,000 cubic feet of water, having a high-water area of 395 acres, fed from a catchment basin of 12.1 square miles. The reservoir is formed by three dams. The back wall of the centre dam has a vertical height of one hundred and thirty-one feet. The walls are of dry rubble stone covering a solidly filled timber crib. The total cost of the reservoir to date is $155,000.

The storage reservoirs of the Eureka Lake and Yuba Canal Company consist of the French reservoir, 661,000,000 cubic feet capacity, area 337.32 acres; Weaver Lake reservoir, 100,000,000 cubic feet capacity; and Faucherie reservoir, 58,800,000 cubic feet capacity, high-water area 90 acres; having, therefore, an aggregate capacity of 819,800,000 cubic feet of water.* The catchment basins of most of these reservoirs are in a rugged, mountainous region, and in ordinary seasons 60 to 80 per cent. of the rain and snow fall flows into the reservoirs.

Distributing Reservoirs.—Independent of these reservoirs, all mines, at convenient distances from their works, have what are called distributing reservoirs, which receive the water from the main ditch for delivery to the

* See report of J. D. Hague, M.E., pp. 15, 16, and 17.

individual claims. These reservoirs are usually small, containing only sufficient water for a few hours' or a few days' run.

The principal distributing reservoirs in the mining districts of California are:

Waldron, N. Bloomfield Mining Co.	5,352,000 cubic feet.
Marlow, N. Bloomfield Mining Co.	1,734,000 cubic feet.
Pine Grove, Milton Mining Co.	11,150,000 cubic feet.
Empire, Milton Mining Co	2,230,000 cubic feet.
Excelsior No. 1, Excelsior Mining Co	15,610,000 cubic feet.
Excelsior No. 2, Excelsior Mining Co.	6,690,000 cubic feet.

DAMS.

Dams are required for the purpose of impounding water in reservoirs, for diverting it from streams, or for storing in the cañons or elsewhere the débris coming from the mines.

Foundation.—The first object sought in selecting a site is a foundation sufficiently solid and impervious to prevent settling of the dam, leakage under its base, and wear in front by water running over its top. Where possible the entire foundation should be in solid rock.

A hard, level, compact rock always affords the best foundation, but where that cannot be obtained any thick, impermeable stratum strong enough to sustain the pressure will suffice. Gravel soil is better than earth, but requires sheet piling to prevent sipage beneath the base of the dam. No reliance can be placed on vegetable soil. In India, where it is impracticable to go down to the bed-rock, stone wells filled with concrete and connected by rows of piles have been used.

In preparing the foundation the soil and all porous material, sand and gravel, is stripped off, and when the solid ground is reached it should be carefully and thoroughly tested by shafts or borings. Where the rock is fissured all loose material should be removed; some engineers recommend covering the foundation with a layer of pud-

TABLE II.

RESERVOIRS

on the Yuba, Bear, Feather, and American Rivers, constructed for mining purposes.

Name.	Owner.	Capacity in cubic feet.
Bowman..............	*North Bloomfield Co*...	930,000,000
Shot Gun Lake........	" " " ..	3,423,816
Island Lake...........	" " " ..	23,027,558
Middle Lake..........	" " " ..	2,395,800
Round Lake...........	" " " ..	2,907,630
Weaver Lake..........	*Eureka Lake Co*......	150,000,000
Eureka Lake..........	" " "	661,000,000
Faucherie.............	" " "	58,800,000
Jackson Lake.........	" " "	15,000,000
Smaller Lakes.........	" " "	50,000,000
English...............	*Milton Co*...........	650,000,000
Fordyce..............	*South Yuba Co*.......	1,075,525,000
Meadow Lake.........	" " "	107,950,000
Sterling..............	" " "	53,975,000
Omega and Blue Tent..	Blue Tent Co........	300,000,000
California.............	California Co........	600,000,000
El Dorado.............	....	1,070,000,000
Smaller reservoirs on the Feather, Yuba, and American rivers.....	....	700,000,000
Total storage.........	....	6,454,004,804

NOTE.—The capacities of the reservoirs whose names are given in *italics* are derived from official sources. The capacities of the other reservoirs are given on the authority of Hamilton Smith, Jr.

dle rammed solidly, which is torn off afterwards, bringing with it all the loose pieces of rock.

Where a hard-pan bottom is used great care should be taken not to crack it. Fanning recommends in such cases that the soil should be carefully removed down to the impervious stratum, on which a puddle of well rammed clay, rolled with not less than a two-ton weight, should be placed, and a puddle wall built. He also suggests the covering of the ground in front with a layer of gravel and clay, and at the toe of the inside face of the dam sheet piling should be driven through the hard-pan to prevent any leakage under the base of the structure, which must be water-tight and have a strong apron placed in front of it to prevent the water from scouring the bed.

Wooden Dams.—On light soil, where there is danger of undermining from the overflow, wooden dams can be built in step form (1 vertical to 3 or 4 horizontal) and provided with aprons; sometimes the aprons are inclined towards the dam, against which their lower ends abut, while at the further end sheet piling is driven and the bed around it protected with rip-rap. The same object is accomplished likewise by two dams erected a short distance apart, the lower one forming a pool or water-cushion for the discharge from the upper one.

There are various forms of wooden dams. They are generally constructed of round logs or hewn timber one to two feet in diameter, laid on each other so as to form in plan a series of cribs from eight to ten feet square, and pinned together by wooden treenails. In the better class of crib-work the timbers are notched and bolted to each other at each intersection with iron drift bolts, the round logs being flattened or notched where they lie upon each other. The bottom timbers are bolted to the bed-rock, the ties are notched and bolted to the stringers, and the cribs are filled with rock. The face of the dam is made water-tight by an outer skin of plank spiked to

the face ribs. These planks are fitted with an outgauge or battened or otherwise calked.

Abutments.—Where abutments are used they should be constructed so as not to contract the width of the stream. They must be securely connected to the ends of the dam, and, if possible, carried so far inland that high water cannot sweep around them; they must be sunk deep and protected from all action of the water, and the ends adjacent to the dam should be rounded. They are constructed of stone or cement, or are built of timber cribs.

Masonry Dams.—Hydraulic mining from its nature does not justify the expense of masonry dams, unless perhaps the reservoirs are designed also for other and more permanent uses. The subject of the construction of masonry dams has been thoroughly investigated by engineers. The annexed profile (Fig. 3), the bounding lines of which are logarithmic curves, has been calculated by Prof. Rankine to serve as a type for masonry dams of any practicable height. "It presents many strong points not found in the usual rectilinear profile, and deserves especial consideration."

The most desirable form of profile for masonry dams is the one which combines the greatest strength with the least amount of material. To determine this it is necessary to know the forces to which the proposed dam is to be subjected, whether constant or variable, and the effects they are likely to produce. The conditions of stability (that the dam may sustain its own weight and withstand both its own weight and the pressure of the water) are then considered, and the profile adopted which combines the greatest strength and stability with economy of material.

The weight of the material composing the structure, and the pressure or thrust of the water which it holds, are the only forces which may be regarded as acting with vigor on a dam. The former is constant; the latter depends on the height of the water behind the dam, and

is consequently variable. The thrust at any point acts normally to the immersed surface, and is not uniformly distributed over the entire face, being zero at the water-line and greatest at the foot of the dam.

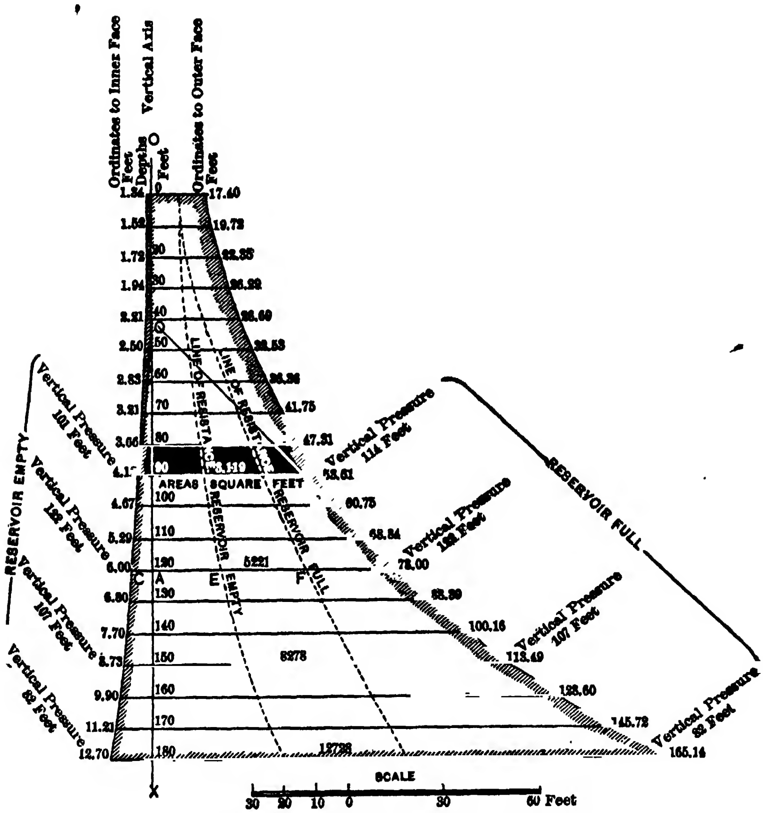


FIG. 3. SECTION OF DAM. PROPOSED BY W. J. M. RANKINE, ESQ.

A dam may yield by sliding on its base or at any horizontal joint, or by rotation about the toe.

In masonry dams the weight of the dam acting vertically, and the pressure of the water acting in directions normal to the surface immersed, are the two components of a resultant, and stability will be secured when this

resultant pierces the base or any horizontal joint within certain defined limits. If the line of the resultant intersects any horizontal plane of the dam outside of these limits, stability is not assured.

The following conditions are indispensable for the stability of dams:

1st. The courses of masonry must be incapable of slipping one over the other, and the wall incapable of sliding on its base.

2d. Neither the material employed nor the foundation must be required to bear too great a pressure.

The stones must not be laid in horizontal courses extending from front to rear, and binders should be freely used. The stability of all dams (or walls sustaining pressure) requires that there should be no continuous joints.

Earthen Dams.—For reservoirs of moderate depth earthen dams are frequently used. Experience sanctions for these dimensions not less than ten feet on top, and a height of over sixty feet is considered risky by many engineers. Trautwine suggests that in properly constructed earthen dams "the top width should be equal to two feet plus twice the square root of the height in feet." The inner slope should be 2½ (base) to 1 (height), and the outer slope 1½ to 1. Flat inner slopes are most desirable, as they increase the stability of the structure and likewise prevent displacement of the pitching. In some instances the toes of the slopes abut against retaining walls in cement. The inner slopes should be carefully faced up to the top with dry rubble-stone pitching at least one and one-half feet deep.

The Pillarcitos reservoir, San Mateo County, has an earthen dam six hundred and forty feet long, twenty-six feet wide on top, and ninety-five feet high. The San Andreas dam is six hundred and forty feet long, twenty-five feet wide on top, and ninety-five feet high. The former has a slope of 2¾ (base) to 1 (height) on the inner, and 2½ to 1 on the outer side. In the latter the inner

slope is 3½ to 1, and the outer slope is 3 to 1. In both cases the puddle walls have been carried down respectively forty-six and forty-seven feet deeper than the base.

The materials selected for the embankment play a very important part. The best combination consists of gravel, sharp sand, and clay, properly proportioned, which give weight, cohesiveness, stability, and imperviousness.* The weight of the wall must be opposed to the thrust, the height and length are determined quantities, and the thickness is the only remaining factor for adjustment.

Puddle Walls.—Engineers differ in opinion as to the value of puddle walls. They are designed to prevent leakage through or beneath the embankment and reach from the top to below the base. They should be from six to eight feet thick on top, increasing downwards by offsets at the rate of about one foot for every three or four in depth.

Where the embankment is composed of loose material and the water comes in contact with the clay puddle, it is advisable to enclose the puddle in concrete, or a watertight wall should intervene between the puddle and the reservoir.

A properly constructed embankment, with the inner slope and the bottom of the reservoir, especially near the toe, securely protected by means of puddle, concrete, or stone facing laid in cement, is considered by some engineers preferable to a puddle wall in the centre of the dam.

Shrinkage of Embankments.—The following are the approximate averages of the shrinkage of embankments according to Trautwine (1882, p. 630):

Gravel or sand	8 per cent.
Clay	10 per cent.
Loam	12 per cent.
Loose vegetable surface soil	15 per cent.
Puddle clay	20 per cent.

* See Fanning, "Water-Supply Engineering," pp. 339–342.

Trautwine determined that one cubic yard of hard rock made on an average 1.7 cubic yards of embankment, or that one cubic yard of rock embankment required 0.5882 of a cubic yard in place. Also that a solid cubic yard when broken into fragments made 1.9 cubic yards of loose heap, 1¾ yards carelessly piled, 1.6 cubic yards carefully piled, 1.5 cubic yards very carelessly scabbled, or 1¼ cubic yards somewhat carefully scabbled.

Dams in California.—Among the most important dams built in California are: the Bowman dam, height one hundred feet, length four hundred and twenty-five

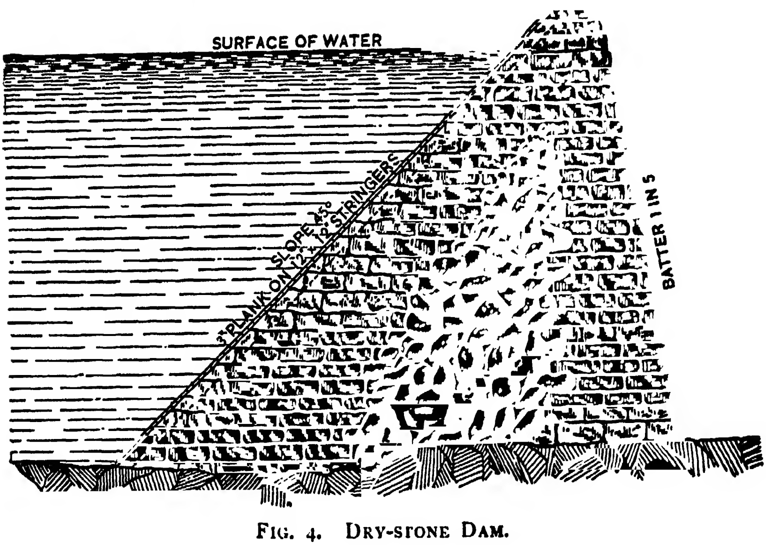


FIG. 4. DRY-STONE DAM.

feet; three dams owned by the Milton Mining and Water Company, forming the English reservoir, the largest of these having a height of one hundred and thirty-one feet; the Fordyce, of the South Yuba Canal Company, five hundred and sixty-seven feet long and seventy-five feet high, catchment basin about forty square miles; the Eureka Lake dam of the Eureka Lake and Yuba Canal Company, length two hundred and fifty feet, height sixty-eight feet.

TABLE III.

*Angles of Repose and Friction of Embankment Materials.**

Material.	Angle of Repose.	Coefficient of Friction.	Ratio of Slope.
			Hor. *Vert.*
Dry sand, fine	28°	.532	1.88 to 1
" " coarse	30°	.577	1.73 " 1
Damp clay	45°	1.000	1.00 " 1
Wet clay	15°	.268	3.73 " 1
Clayey gravel	45°	1.000	1.00 " 1
Shingle	42°	.900	1.11 " 1
Gravel	38°	.781	1.28 " 1
Firm loam	36°	.727	1.38 " 1
Vegetable soil	35°	.700	1.43 " 1
Peat	20°	.364	2.75 " 1
Masonry on clayey gravel	30°	.577	1.73 " 1
" " dry clay	27°	.510	1.96 " 1
" " moist clay	18°	.325	3.08 " 1
Earth on moist clay	45°	1.000	1.00 " 1
" " wet clay	17°	.306	3.26 " 1

* See "Treatise on Water-Supply Engineering," by J. T. Fanning, p. 345.

All the foregoing dams are built of dry rubble stone and faced with a water-tight lining of planks.

The Tuolumne County Water Company has built several timber crib dams, the largest of which is across the south fork of the Stanislaus River. This dam, which is three hundred feet long and sixty feet high, rests for its entire base on solid granite bed-rock. The cribs, constructed of round tamarack logs from two to three feet in diameter, are about eight feet square from log to log (ten feet centre to centre), and the timbers are pinned together with wooden treenails. The cribs have no rock filling.

The face is formed of flattened three-inch timber pinned with wooden treenails to the crib and calked with cedar bark. The flood water passes over the crest of the dam for the entire length. The water is drawn off by several gates, one above the other, placed on the inclined water-face. The dam was built in 1856. Its total cost did not exceed $40,000. Pine dams owned by this company, constructed on the same plan, have decayed, while cedar cribs are still in perfect order. The Spring Valley and Cherokee Company's Concow reservoir in Butte County is formed by two earthen dams, each about fifty-five feet in height; one of these, which is used as a waste, has its lower side built of heavy brush embedded in the earth.

THE BOWMAN RESERVOIR AND DAM.

This reservoir was designed for the supply of water during the dry season of the year to the gravel mines operated by the North Bloomfield Mining Company. It is located in a mountain valley, on Big Cañon Creek, a branch of the Yuba River.

It is fed from a gross catchment area of 28.94 square miles. Higher up on the same stream there are several other reservoirs owned by the Bloomfield and Eureka Lake companies, the upper one (Eureka Lake reservoir) holding 661,000,000 cubic feet of water. In ordinary seasons

TABLE IV.

Some of the Principal Dams in California.

Name.	Owner.	High-Water Area.	Top Height.	Top Length.	Cost.	Barometrical Elevation.	Catchment Area.
		Acres.	*Feet.*	*Feet.*		*Feet.*	*Acres*
Bowman	North Bloomfield Co......	500	100	425	$151,521	5,450	12,093
Saw Mill Flat.	North Bloomfield Co......	$80\frac{6}{10}$	$39\frac{2}{10}$	..	The total amount expended on all these dams and reservoirs is $246,000.	5,780	....
Shot Gun Lake	North Bloomfield Co......	$26\frac{2}{10}$	10	..		6,410	....
Island "	North Bloomfield Co......	$48\frac{8}{10}$	$12\frac{8}{10}$	..		6,690	....
Middle "	North Bloomfield Co......	$11\frac{2}{10}$	12	..		6,460	....
Crooked "	North Bloomfield Co......	$10\frac{8}{10}$	3	..		6,510	....
Round "	North Bloomfield Co......	$8\frac{1}{10}$	11	..		6,590	....
Fall Creek...	North Bloomfield Co.. ...	....	....	..		6,690	....
English	Milton M. Co..	395	131	331	$155,000*	6,140	7,745
Milton Dam..	Milton M. Co..	10	5	..	....	5,670	17,637
Eureka Lake.	Eureka Lake Co...... ...	$337\frac{2}{10}$	$68\frac{2}{10}$	250	35,000	6,480	3,170
Jackson "	Eureka Lake Co...........	20	5	..	....	5,410	
Faucherie "	Eureka Lake Co	90	21	..	8,000	6,060	3,262
Weaver "	Eureka Lake Co...........	$83\frac{5}{10}$	$21\frac{8}{10}$	..	....	.....	....
Meadow "	South Yuba Co.	262	28	500	....	7,040	
Fordyce (enlarged)....	South Yuba Co.	1200	75	650	....	7,000	... .
Sterling	South Yuba Co.	....	30	300	....	7,200	....
Tuolumne....	Tuolumne Co..	....	60	300	40,000	8,000	....
Pillarcitos....	Spring Valley Water Co....	....	95	640	....	696	....
San Andreas..	Spring Valley Water Co....	....	93	640	....	455	....

* Includes cost of the three dams, which form the reservoir. The height and lengths given are for the main structure.

	1872–1873			1873–1874		
	Snow.	Rain and Melted Snow.	Draught and Waste.	Snow.	Rain and Melted Snow.	Draught and
	Inches.	*Inches.*	*Cubic Feet.*	*Inches.*	*Inches.*	*Cubic*
September......... ...	...	0.25	....	..	.	35 m
October................	4.5	0.73	11 million	....	1.24	40
November.............	6.0	5.43	14 "	3.5	4.37	24
December.............	....	17.41	67 "	140.0	23.47	52
January.	29.5	5.73	213 "	85.0	21 53	119
February	137.0	16 17	187 "	82 0	9 98	152
March	18.0	3.82	184 "	127.0	17.73	161
April...	8.5	3.20	161 "	19.0	5.41	138
May	13.0	2.65	374 "	17.5	3.93	1094
June	....	....	181 "	....	0.45	1147
July	....	0.06	167 "	....	....	368
August	....	....	118 "	....	0.08	207
Totals.....	216.5	55.45	1677 million	480.0	88.19	3537
+ or – for stored water	....	....	+114 "	...	....	+147
Gross yield............	....	....	1791 million	. ..	....	3684
Gross precipitation in 18.9 miles.	....	....	2434 "	.. .	....	3873
Per cent. of yield to precipitation......	73.6 per cent.*			95.1 per cent.*		

NOTE.—In seasons of large rain-fall the Big Cañon reservoir receives the surplus w at an elevation of 5,200 feet above sea-level, which is the lowest point in the Big Cañor

* These years the Faucherie Dam was of low height, and considerable water was

TABLE VI.

n and Snow Fall at Big Cañon (Bowman) Reservoir, and Total Catch of Water from it

5	1875–1876			1876–1877			1877–1878			
Draught and Waste.	Snow.	Rain and Melted Snow.	Draught and Waste.	Snow.	Rain and Melted Snow.	Draught and Waste.	Snow.	Rain and Melted Snow.	Draught and Waste.	Snow.
Cubic Feet.	*Inches.*	*Inches.*	*Cubic Feet.*	*Inches.*	*Inches.*	*Cubic Feet.*	*Inches.*	*Inches.*	*Cubic Feet.*	*Inches.*
108 million	...	....	106 million	...	0.41	161 million	...	...	135 million	1.0
72 "	.	3.09	55 "	7.5	10.76	98 "	....	1.52	62 "	6.0
60 "	25.5	23.23	315 "	.	0.87	11 "	10.0	8.26	11 "	1.5
116 "	25 5	10.77	286 "	..	....	143 "	16.0	1.71	17 "	6.0
230 "	152.5	17 62	235 "	77.5	14.33	91 "	91.5	27.00	73 "	60.5
182 "	90.0	11.70	205 "	3.5	3.18	95 "	114.5	21.21	81 "	45.0
196 "	129.0	18.07	76 "	3.5	7.49	68 "	31.0	10.07	107 "	91.5
82 "	14.0	5.02	372 "	14 5	3 17	108 "	25.0	2.57	104 "	39.5
287 "	7.5	0.09	1032 "	8.5	3.33	119 "	....	2.06	568 "	4.5
46 "	...	0.36	978 "	....	1 17	124 "	....	0.10	320 "	...
125 "	...	1.28	250 "	....		138 "	....	0.09	201 "	...
133 "	...	...	181 "	....	.	140 "	....	0.13	207 "	..
1727 million	444.0	93.03	4091 million	115 0	44.71	1296 million	290.0	64.72	1886 million	255.5
−46 "	....	...	+6 "	...	....	−26 "	....	...	+252 "	....
1681 million	....	....	4097 million	....	....	[illegible] million	....	....	2138 million	...
2208 "	...	....	4085 "	..	....	1963 "	....	....	2842 "	..
ent.*	Break of Faucherie dam afforded this season extra drainage from 5 1-10 miles.			64.2 per cent			75.2 per cent.			

a) Lake Basin, 4.95 square miles, and Faucherie Basin, 5 1-10 miles. With rain-fall of 75 inches and under nothing is received from F
to a height of 7,800 feet above sea-level. The country is generally wooded, with some meadows, and a considerable extent of bare
r from Faucherie Basin. No allowance is made in the above table for evaporation from surface of reservoir, which, when full, has a

, 18.9 *square miles.*

	1879–1880			1880–1881			1881–1882		
Draught and Waste.	Snow.	Rain and Melted Snow.	Draught and Waste.	Snow.	Rain and Melted Snow.	Draught and Waste.	Snow.	Rain and Melted Snow.	Draught and Waste.
ubic Feet. 01 million	*Inches.* ...	*Inches.* ...	*Cubic Feet.* 201 million	*Inches.* ...	*Inches.*	*Cubic Feet.* 201 million	*Inches.* 2.5	*Inches.* 2.33	*Cubic Feet.* 133 million
36 "	23.0	3.41	140 "	....	0.65	172 "	11.5	6.09	204 "
91 "	25.0	9.62	195 "	3.5	0.15	176 "	33.5	4.25	152 "
50 "	63.0	15.00	175 "	110.5	25.05	175 "	1.5	10.78	163 "
54 "	57.5	9.27	171 "	38.0	27.82	102 "	59.5	11.46	150 "
06 "	78.5	8.17	83 "	24.5	15.08	455 "	72.5	7.47	153 "
91 "	55.0	9.51	77 "	55.5	7.29	102 "	125.0	15.17	96 "
75 "	176.0	31.72	91 "	..	4.44	519 "	44.0	7.96	72 "
50 "	20.5	8.90	192 "	....	1.22	397 "	...	1.16	212 "
11 "	...	....	1056 "	....	3.52	327 "	....	0.42	513 "
10 "	....	....	392 "	....	....	107 "	....	....	195 "
07 "	...	....	211 "	....	...	131 "	...	....	209 "
82 million	498.5	95.60	2984 million	232.0	85.22	2864 million	350.0	67.09	2252 million
46 "	....	....	+153 "	....	....	−40 "	...	...	−134 "
23 million	....	....	3137 million	....	...	2824 million	....	...	2118 million
13 "	...	....	4107 "	...	...	3741 "	....	....	2946 "
it.	74.7 per cent.			75.4 per cent.			71.9 per cent.		

asin. With rain-fall under 60 inches but little is received from Faucherie Basin. The rain-gauge at Big Cañon is placed

cres. Table VI. was calculated by Mr. H. C. Perkins, Supt. North Bloomfield Gravel-Mining Co., from official data.

these upper reservoirs retain all the water flowing into them, reducing the catchment basin of the Bowman to about nineteen square miles.

The mean annual rain and snowfall at the Bowman dam is about seventy-five inches, of which seventy-five per cent. flows into the reservoir.

Two dams are needed to impound the water. The main one, placed across the narrow gorge forming the outlet of the valley, has a maximum height of one hundred feet (96.25 feet above the datum base line) and an extreme length on top of four hundred and twenty-five feet, and is the largest on the coast.

The smaller dam, placed across a gap near the mouth of the valley, has a maximum height of fifty-four feet and an extreme length on top of two hundred and ten feet. It is fitted with waste-ways, and over it is discharged all the surplus water from the reservoir.

High-water mark is fixed at a point one and one-half feet below the summit of the main dam; at this height the reservoir contains 918,000,000 cubic feet of water with a surface area of over 500 acres. By placing temporary flush boards on the top of the waste dam the water is raised to the ninety-six feet line (above datum base), increasing the quantity of water stored to 930,000,000 cubic feet.

The stream feeding the reservoir has a maximum flow during great freshets of 5,000 to 7,000 cubic feet of water per second. The existence of other reservoirs higher up the stream adds to the danger from great floods, and therefore the Bowman dams have been designed to withstand not only freshets in the cañons, but also any additional influx of water caused by the breaking of the upper dams.

Main Dam.—Figure 5 A shows a profile across the cañon, being a longitudinal section through the dam. Figure 5 B gives a cross section at its extreme height.

It rests on solid granite bed-rock, which is sufficiently free from seams to prevent any considerable leakage through crevices in the rock.

The dam was built in 1872 to the height of seventy-two feet, as shown by the sketch, being a timber crib formed of unhewn cedar and tamarack logs, notched and firmly bolted together, and solidly filled with loose stones of small size. A skin of pine planking, spiked to the water-face, forms a water-tight lining. During the years 1875 and 1876 the dam was increased to the height of ninety-six and one-fourth feet above datum line (one hundred feet extreme height) by filling in a stone embankment on the lower side of the old structure, faced with heavy walls

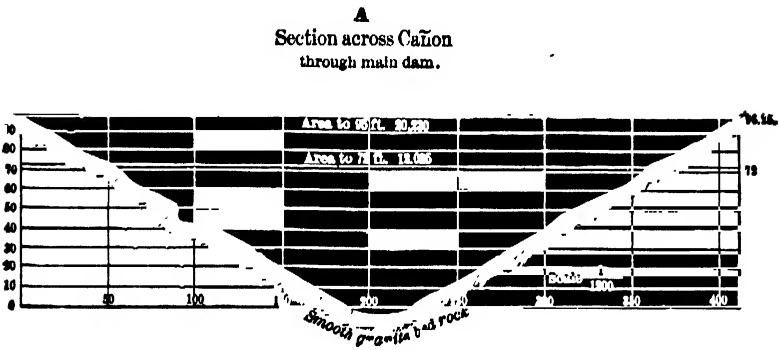


FIG. 5A. THE BOWMAN MAIN DAM.

of dry rubble stone of large size. The down-stream face wall is fifteen to eighteen feet thick at the bottom, diminishing to six or eight feet at the top. Most of the face stones in this wall are of good size, weighing from three-fourths to four and one-half tons, and there are many of equal weight in the backing.

The lower portion of the wall is seventeen and one-half feet high, with a batter of fifteen per cent. It is built of heavy stone, with ranged horizontal beds and with the face stone tied to the backing by long iron ties.

The upper portion of the wall is built with a slope of forty-five degrees, and the face stones are bedded on an angle of twenty-two and one-half degrees, thus dividing

the angle between a horizontal bed and a bed at right angles to the face. No attempt at range work was made

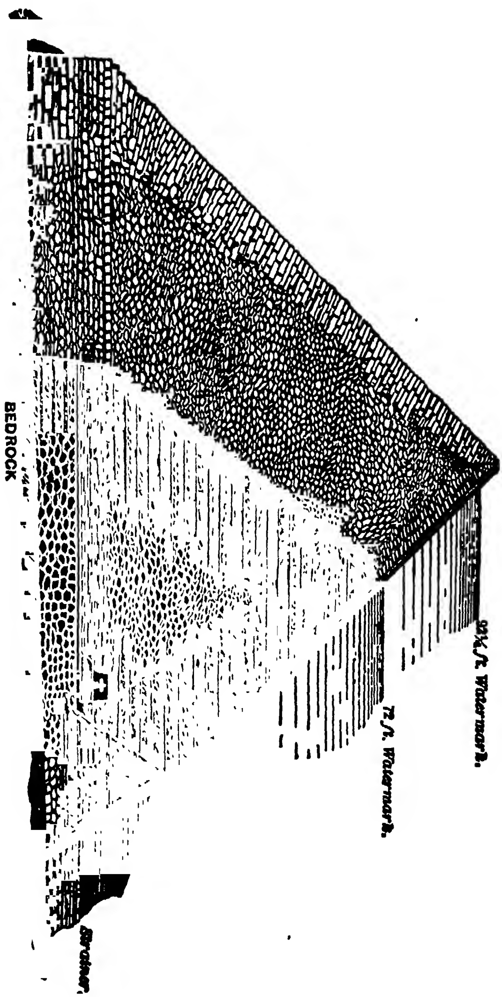


Fig. 5B. The Bowman Main Dam.

in this upper portion of the wall. Above the sixty-eight feet line ribs of flattened cedar, eight inches thick, are built into the up-stream face wall and are tied to it by iron rods

three-fourths inch in diameter and five feet long. On these ribs a planked skin is firmly spiked. This planking is of heart sugar pine, three inches thick and eight inches wide, with planed edges fitted with an outgauge, similar to ship planking. The plank was put on nearly thoroughly seasoned, and swells sufficiently to make the face practically water-tight without battening or calking the joints. The openings at the joints made by the outgauge suck in small particles of vegetable matter, which take the place of calking to a great extent. At the bottom the plank is fitted to a firm bed-rock and calked with pine wedges. There are three thicknesses (nine inches) on the lower twenty-five feet, two thicknesses (six inches) on the next thirty-five feet, and one thickness on the upper thirty-six feet.

From past experience it is believed that the planking will remain sufficiently sound for twenty years at least.

A culvert extends through the dam, as shown by Fig. 5 B, through which the water is drawn from the reservoir. This culvert is built with heavy dry-rubble foundation and walls, and is covered with granite slabs sixteen to eighteen inches thick and six and one-third feet long.

Three wrought-iron pipes of No. 12 iron, each eighteen inches in diameter, pass through the water-face of the dam. Their upper mouths are protected by a strainer, formed of two-inch plank, anchored to the bed-rock. A separate valve or gate is placed at the lower end of each pipe; the water passing through the gates, aggregating a flow of 280 cubic feet per second when the three are open, discharges into a covered timber sluice, seven and one-half feet wide by one and three-fourths feet high, passing to the lower edge of the dam, and thence on to the solid rock of the creek bed. The gates are approached by a walk way above the sluice. The crest of the dam is formed by a coping of hewn heart-cedar timber, eight-

een inches wide on top, securely anchored by iron bolts to the stone wall.

It is not probable that any water will ever pass over the crest of the main dam, except in case of a break at the large reservoir higher up the stream. Great care was taken in building the down-stream face wall of the dam for any such possible emergency. Should this happen a large quantity of water would enter the structure, owing to the inclined beds of the face stone and the flat slope of the wall, which water would seek its discharge through the interstices purposely left in the nearly vertical portion of the lower wall. To prevent the consequent hydrostatic pressure, which would accumulate at the base of the dam to perhaps twenty pounds to the square inch, from forcing out the lower face, the wall was carefully built and tied with iron rods.

There are 55,000 cubic yards of material in this structure, weighing about 85,000 tons; the hydrostatic pressure, with the water-line ninety-five feet above datum, against a vertical plane of that height across the cañon at the dam site will be 21,745 tons. The dam is built V-shaped, with the vertex of the angle of 165° pointing up stream. This mode of construction adds somewhat to the stability of the structure. The cost was $151,521.44. The rather peculiar construction of this dam was due to the following causes:

The stone cliffs in the vicinity are composed of an exceedingly hard granite with poor cleavage, but with great numbers of short cross seams, making it most costly to quarry stone of large dimensions.

No limestone existing in the vicinity, the cost of transporting lime was so great as to prevent its use.

On the side of the mountain, at the distance of about one mile, there was a large pile of loose stone, too irregular in shape to be used in wall-building, but of good quality for an embankment. It was found to be cheaper to build a tramway to this stone and haul it to the work

than to quarry from the cliffs nearer the dam. Hence, the supply of material being abundant, flat slopes of 45° for the wall were adopted, which allowed very much lighter face walls to be used with safety than would have been the case had they been more nearly vertical.

The stone for these face walls was quarried from solid rock, and cost in place three or four times more than the loose stone brought from the mountain side. When in the future the timber logs forming the cribs in the original seventy-two feet dam decay, there will be some slight subsidence of the superincumbent stone. The depth of the stone is so considerable and the slopes of the walls are so flat that it is believed this subsidence will not be noticeable.

Waste Dam.—Figures 6A and 6B show longitudinal and cross sections of the waste dam. This is a crib of round cedar timbers varying from twelve to thirty inches in diameter, notched down to heart wood at the joints, and firmly bolted with three-quarter and one-inch drift bolts. The foundation logs are all fastened to the bedrock with one and one-half inch bolts.

The cribs are solidly filled with granite rocks varying from several tons to a few pounds. No sand or fine stone was used in this filling. A plank facing of three-inch heart sugar-pine is spiked on the water-face, making a water-tight lining similar to that on the main dam.

The crest of the original dam is ninety-two and one-half feet above datum line, being four feet lower than the summit of the main dam. A light superstructure of four feet allows the water to be raised to the height of the main dam. The waste dam is provided with twenty-eight escapes, each four feet wide and eleven feet deep. These waste-ways are closed, when all danger from freshets is passed, with boards two inches thick, eight inches wide, four and one-half feet long, laid horizontally, and sliding to their places one above the other on the inclined

slope of the water-face. This style of gate has been found by long experience to be the best.

The weight of the dam is about 6500 tons, and the hydrostatic pressure, with the water line 95 feet above

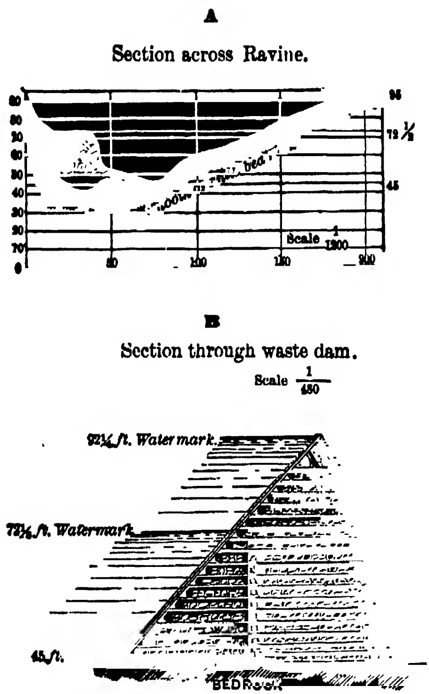


Fig. 6. Bowman Waste Dam.

datum line, against a vertical plane of that height across its upper face, is 2571 tons.

It is believed that the structure is sufficiently stable to allow a flood of 16,000 cubic feet of water per second to pass with safety through the wastes and over its crest.

The water passing over the dam falls on bare granite bed-rock, and thence down a steep gorge.

From past experience in the use of cedar timber it is safe to assume that the life of this structure will be from twenty-five to thirty years, and possibly longer. Its cost was $15,000.*

Débris Dams.—Débris dams are obstructions placed across the beds of streams for the purpose of holding back the sand and gravel coming from the mines, to prevent their entering into the navigable streams and damaging the land in the valleys below. They may be placed either in the mountain cañons or in the valleys where storage room can be conveniently obtained. These dams or barriers may be composed of stone, wood, or brush, as circumstances require. The structures are not designed to impound water, but simply to check the velocity of the current carrying the mining and other débris and to allow the deposit of the material behind them, and therefore they partake more of the character of retaining walls than of water dams.

"The deposits in the streams consist of stones several cubic feet in volume—cobble, gravel in all sizes, sand in various degrees of fineness, and a mixture of extremely fine sand and clay, popularly known as 'slickens.' This latter material, being easily transported, is constantly in motion, even in the low stages of the stream. The same is probably also true of the finer sands, and in particular streams is true of the gravel, at least in the upper portions, where the beds are confined and where the slopes are steep.

"When the high stages of water come they find the beds of the streams dotted at the ends of the mining sluices with mounds of detritus, which sometimes form dams across the beds of the stream.

"The effect of the flood-water is to sweep these deposits, excepting perhaps the largest pieces of stone, and to carry them away to lower parts of the river. The fall of some of the principal streams serving as outlets to the mines is in places 50 and even 75 feet to the mile. A rise of 20 feet more or less in a narrow bed with such a fall is sufficient to move material with great effect.

"The periods and stages of high water vary very much here as elsewhere; but the rainfall, be it large or small—and there is great variation in this respect—comes mainly in two or three months, so that there is, except

* The above description of the Bowman dams is essentially the same as that written for the author by Hamilton Smith, Jr., who planned and constructed the dams.

in very dry years, a period of some length in which the water is high from rains.

"There is also a period of high-water in the spring, due to melting of the snow which has accumulated during the winter on the higher altitudes of the Sierra.

"The mass of material thus put in motion in narrow and steep river-beds is carried along to the lower parts of the rivers, each tributary contributing its share of flood-water and detritus, and uniting to form at or near the edge of the foot-hills the rivers to which we have given names. As the detritus reaches lower portions, the streams, less concentrated and with constantly diminishing fall in the bed, find themselves unable to carry to the lower course the load which they transported in the upper. When these streams, as they were before mining was begun, reached the plains of the Sacramento Valley, the fall of the beds diminished to a very few feet per mile, perhaps 3 or 4, so that, all along the whole lower course of the river, the bed first, and afterwards the plains bordering the river where the banks were low, became depository places for the material the river was no longer able to carry. The river bed in the plains first becomes obliterated by deposits, and then the alluvial lands adjoining become a waste of sand, gravel, and 'slickens.' Instead of a river bed there is a wide plain overflowed at high stage, through which, meandering in constantly varying channels, the summer river pursues its devious course." *

The topography of the country along the lines of the mountain streams, though rugged, affords every facility for carrying out successfully a plan for storing the tailings. The banks are generally of great height, with slopes which vary from fifteen to fifty degrees. The general slope is about thirty-five degrees, and "an elevation of fifty feet adds one hundred and forty to the width, which extended width," says Col. Mendell, "reduces the height of floods, the cubes of the heights being proportional to the squares of the widths. Doubling the width reduces the height one third, which reduction in height reduces the suspending power of the water and the exposure of the structure to floods." † The storage capacity is consequently increased by this additional width as the bed of the stream is elevated.

The chief obstacles to be encountered in the erection

* Annual Report of the Chief of Engineers U. S. Army for 1881, Appendix MM$_7$.

† Col. Mendell's Report on Mining Débris in California Rivers, p. 41.

of these dams arise from the present condition of the beds of the streams, the accumulations of past years, and the current mining operations. The channels in their present state contain large quantities of such detritus. In the Yuba alone above Smartsville over 80,000,000 cubic yards are estimated to be deposited in the cañons, and between Smartsville and the mouth of the Yuba some 700,000,000 cubic yards are said to be in the bed of the stream. According to the testimony given in the case of Keyes *vs.* Little York Gold Washing and Water Company, 86,000,000 cubic yards were estimated in 1878 to have been deposited in the bed of Bear River above the plains, and 36,000,000 cubic yards below the foot-hills to its mouth, a total of 122,000,000 cubic yards.

Without entering further into details of numerous other streams in which débris is or has been deposited for the past thirty-five years, suffice it to say that, mining or no mining, it is only a question of time as to when a large part of this mass will move down into the lowlands, unless measures are taken to prevent the continuous eroding action of the waters and also to impound the material, which can be done only by the construction of a system of permanent dams. Such structures would prevent the streams from eroding the deposits to their original beds, which otherwise, under certain conditions, must sooner or later occur. They would hold in check the accumulations of sand and débris now stored in the cañons, and would permit the continuation of mining without detriment to the interests of others.

"It may be asked," says Col. Mendell, "whether the protection afforded in this way will be complete and include all grades of mining tailings. This cannot be claimed. The suspensory matter of fine sands and clay cannot be restrained in this way or by any other method which does not provide a settling basin in which the water can be maintained in a quiescent state for some time.

"It may also be expected that during the flood stages in the early period of development a certain portion of material of every grade may be suspended, and thus pass the crest of the barrier; but it is to be remarked

that as the width is increased the suspensory power is diminished, so that the degree of protection becomes greater as the system is developed. We can imagine a condition of a river when comparatively little is carried suspended, and nearly the whole of the material transported is rolled in waves on the bottom.

"This condition is more and more approached as the dams are raised. It seems, therefore, to be good policy to give the first dam in the cañons considerable height.

"It will be understood that permanent protection can be attained only by building dams in proportion to the amount of detritus turned out by the mines. The system must be continued at least as long as the mines are worked.

"If this system of restraint had proceeded *pari passu* with mining during the past thirty years it can hardly be doubted that the condition of the country affected would to-day have been much better than it is." *

The height of floods in the Yuba is only twelve feet at the Narrows, and the water is fully loaded with all the material it is capable of transporting. To insure protection permanent structures are therefore required. On sand or gravel bottoms mattresses of trees or brush may be used to prevent settling; but where the supply of rock is abundant, convenient, and cheap, masses of stone can be blasted from the side hills, and, by means of derricks or otherwise, be easily arranged as required. The larger the rocks are the better; the largest being put on the down-stream side, so placed as to permit the draining through of the water; the smaller rocks on the up-stream side. The slopes on both sides should conform to the requirements of the structure. As the dam is built the material will gradually deposit itself against it on the up-stream face; the water draining through the rocks leaves behind in the dam the sand, which gradually fills up the spaces as the bed of the river is raised. Waste-ways may be readily provided on one or both sides of the dam, which would have the practical effect of lengthening the crest of the dam and of thereby reducing the depth of water passing over it in freshets, in the proportion already

* Col. Mendell's Report on Mining Débris in California Rivers, p. 42.

stated. This arrangement will lessen the exposure of the lower face and toe of the dam.

In time of great flood the crest will be submerged to a greater or less degree, depending on the width of the structure and the volume of water discharged by the stream. This would be of little consequence, as the work should be especially designed to permit of the flood waters passing over it, the stability of the dam being assured by the size and weight of the stones exposed to the water.

The stability of a structure of this character is dependent upon conditions differing from those which apply to a structure composed of stones united by a bond, such as an ordinary retaining wall. In the latter case, if the bond is sufficient to make the wall practically a monolith, its stability will be complete if it be given weight enough to prevent it from sliding on its base, and such proportions that it can have no motion of rotation about its toe.

The force tending to move or overthrow the bonded dam is equal to the weight of a prism of water whose base is the area immersed, and whose height is the vertical distance of the centre of gravity from the water-level. The point of application of this thrust is situated at one-third of the height of the water measured from the base. The direction of the thrust is normal to the surface.

The problem is an exact one. The thrust is known in its magnitude, its point of application, and its direction, and the problem of proportioning a wall of masonry to resist this thrust admits of complete solution.*

But the detritus barriers are composed of *pierres-perdues*, or what is commonly known as "rip-rap." There can be little bond in such a structure. Careful placing of stones may, it is true, impart something like a bond, but

* See Rankin, Krantz.

this cannot be safely relied upon as a source of strength. Each stone, being practically independent of its neighbors, must rely upon its own resisting quality to maintain its place in the structure.

It follows that where the floods are great and the exposure consequently large the stones must be proportionately large and heavy.

The interior of a structure of this kind, being protected from the action of the water and held in place by superincumbent weight, may be composed of sizes of stone which it would be unsafe to place on the crest and exposed surfaces. The stones of the crest and on the lower slope are most exposed, and consequently must be of the largest sizes. The force that tends to move them is not hydrostatic pressure, but the force and impact of great volumes of water moving with high velocity.

Such a structure, composed of rubble stone and unable to impound water, would be exposed to the pressure of the material which is slowly deposited behind it. The maximum horizontal pressure from this source alone would be reached when the plane of fracture of the earth bisects the angle which will be formed by the earth sloping back from the foot of the wall on its angle of repose; therefore the weight of such a prism can be easily calculated.

As the dam fills up, the pressure of the material on itself, owing to its composition, would cause it to consolidate (cement), thus continually changing the angle of repose, until finally, when even with the crest, there would be comparatively no horizontal thrust or pressure on the dam, the structure simply protecting the face of the deposit from erosion. Therefore such barriers, constructed with proper materials on the well-known principles of dam-building, could not fail to hold back the débris.

As these dams are not water-tight, and are composed of large masses of rubble stone without bond, it is difficult to see how, in the event of a breach, the inhabitants below

would suffer, nor can it be conceived how a total destruction of the structure could occur. The dam might settle and its usefulness be temporarily impaired, but the only effect that could result in the event of a breach would be a return to the condition of affairs at present existing. As the waters are already charged to their fullest extent, no larger quantity of débris could be transported to a greater distance in a single flood. The report of Lieut.-Col. G. H. Mendell to the Secretary of War (1882) treats in detail the remedial measures proposed, and shows "their necessity even in the event that no further contribution be made to mining detritus in the beds of streams."

CHAPTER IX.

MEASUREMENT OF FLOWING WATER.*

Weirs.—The direct measurement of flowing water in a stream or channel can be made in various ways. Occasionally gauge wheels are used, but the method is expensive. Gauging by rectangular overfalls (weirs) of certain dimensions and under certain circumstances gives results within one per cent. of absolute exactitude (Francis' formula).

In employing this method the height above the crest of the surface of still water, some little distance back from the weir, must be carefully measured. It is also desirable that there should be no considerable current to the water at the place of measurement.

Orifices.—Flowing water is measured also by its discharge under pressure through an aperture of regular section. Though it is not theoretically correct, there will be no practical error in assuming the average head to be from the centre of the aperture when the width is considerably less than the height of the water above the top of the opening.

Open Channels.—The measurement of the surface velocity of water passing through a flume or canal of uniform size can be used to determine its discharge, and in some cases the simple calculation of discharge made by

* For details on the subject of the measurement of water see "The Mechanics of Engineering," by Julius Weisbach, translated by E. B. Coxe; Francis' "Lowell Hydraulics"; "Report Mississippi River," by Humphreys and Abbot; "Hydraulic Manual," by Louis D'A. Jackson; "The New Formulæ for the Mean Velocity of Discharge of Rivers and Canals," by W. R. Kutter; "Hydraulic Tables," by Thos. Higham; "A Treatise on Water-Supply Engineering," by J. T. Fanning; "Experiments on the Flow of Water," by A. Fteley and E. P. Stearns, vol. xii. "Transactions of the American Society of Civil Engineers."

multiplying the mean velocity due to the grade by the average cross section is sufficiently accurate. The discharge of small streams is obtained more exactly by filling vessels of known capacity.

Formula for Discharge over Weirs.—In gauging large quantities of water over weirs Fteley and Stearns's general formula can be used for the discharge over the simplest form of sharp-crested weir, unaffected by end contractions or velocity of approach. If these conditions exist the corrections for them must be made separately.*

The formula is

$$Q = 3.31\ LH^{\frac{3}{2}} + 0.007\ L$$

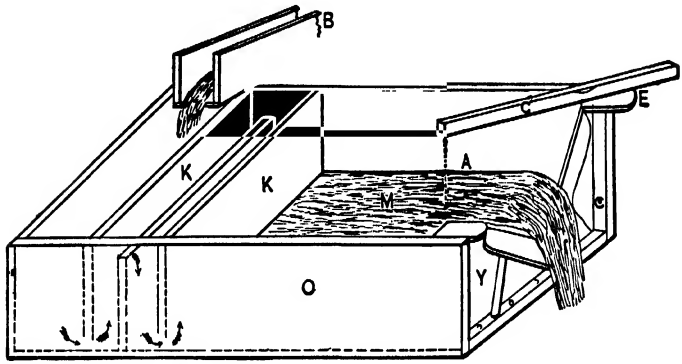
Q is the quantity in cubic feet per second, L the length of the weir, and H the depth on the weir corrected for velocity of approach. This formula does not apply to any depth of the weir less than 0.07 feet.

Discharge through Triangular Notches.—The right-angled triangular notch of thin sheet iron is a very convenient way of measuring the discharge of water. According to Prof. Thompson's experiments, the discharge in cubic feet per second $=$ head$^{\frac{5}{2}}$ (in inches) $\times$ 0.0051.

To use the notch, construct a weir box, O, with a triangular notch, Y, made of iron, fitted in one end. The edge of the notch must be sharp and bevelled out, and the inside face must be placed at right angles to the surface of the water, M. Place in the box baffle boards or strips, K K, to render the surface of the water near the point A uniform or still (A is taken about 18 to 24 inches back from the weir plate Y). Place a spirit-level or straight-edge C on the weir plate at E; measure the distance at A from C to surface of water. Subtract this from H, and find the difference in column marked *h* of Table VII. Opposite *h*,

* See "Transactions American Society Civil Engineers," vol. xii. p. 32.

in column Q, will be found the number of cubic feet of water flowing over the notch in one minute.



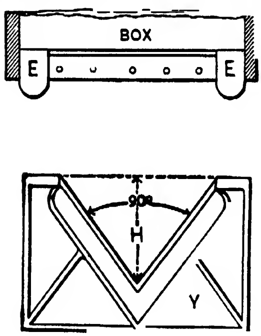


FIG. 7. CONSTRUCTION OF TRIANGULAR WEIRS.

THE MINER'S INCH.

The miner's inch of water is a quantity which varies in almost every district in California; no one gauge has been uniformly adopted, nor has any established pressure been agreed on under which the water shall be measured. In some counties there are 10, 11, or 12 hour inches, and in others there is a 24-hour inch. The apertures through which the water is measured are generally rectangular, but vary greatly in width and length, being from one inch to twelve inches wide and from a few inches to several feet long. The discharges are through 1-inch, 1½-inch, 2-inch, and 3-inch planks, with square or with square and chamfered edges, combined or not, as the case may be. The bottoms of the openings are sometimes flush with the bottoms of the boxes, sometimes raised above them. The head may denote the distance above the centre of the aperture, or

TABLE VII.

Discharge of Water through a Right-angled Triangular Notch.

Calculated by W. R. Eckart, C.E.

h Head, inches.	Q Quantity per min., cu. ft.	h Head, inches.	Q Quantity per min., cu. ft.	h Head, inches.	Q Quant. per min, cu. ft.	h Head, inches.	Q Quant. per min, cu. ft.	h Head, inches.	Q Quantity per min., cu. ft.
1.05	0.3457	3.25	5.827	5.45	21.22	7.65	49.53	9.85	93.18
1.10	0.3884	3.30	6.054	5.50	21.71	7.70	50.34	9.90	94.37
1.15	0.4340	3.35	6.285	5.55	22.20	7.75	51.16	9.95	95.56
1.20	0.4827	3.40	6.523	5.60	22.70	7.80	51.99	10.00	96.77
1.25	0.5345	3.45	6.765	5.65	23.22	7.85	52.83	10.05	97.98
1.30	0.5896	3.50	7.012	5.70	23.74	7.90	53.67	10.10	99 20
1.35	0.6480	3.55	7.266	5.75	24.26	7.95	54.53	10.15	100.43
1.40	0.7096	3.60	7.524	5.80	24.79	8.00	55.39	10.20	101.67
1.45	0.7747	3.65	7.788	5.85	25.33	8.05	56.26	10.25	102.92
1.50	0.8432	3.70	8.058	5.90	25.87	8.10	57.14	10.30	104.18
1.55	0.9153	3.75	8.332	5.95	26.42	8.15	58.03	10.35	105.45
1.60	0.9909	3.80	8.613	6.00	26.98	8.20	58.92	10.40	106.73
1.65	1 070	3.85	8.899	6.05	27.55	8.25	59.82	10.45	108.02
1.70	1.153	3.90	9.191	6.10	28.12	8.30	60.73	10.50	109.31
1.75	1.240	3.95	9.489	6.15	28.70	8.35	61.65	10.55	110.62
1.80	1.330	4.00	9.792	6.20	29.28	8.40	62.58	10.60	111.94
1.85	1.424	4.05	10.10	6.25	29.88	8.45	63.51	10.65	113.26
1.90	1.522	4.10	10.41	6.30	30.48	8.50	64.45	10.70	114.60
1.95	1.625	4.15	10.73	6.35	31.09	8.55	65.41	10.75	115.94
2.00	1.731	4.20	11.06	6.40	31.71	8.60	66.37	10.80	117.29
2.05	1.841	4.25	11.39	6.45	32.33	8.65	67.34	10.85	118.65
2.10	1.955	4.30	11 73	6.50	32.96	8.70	68.32	10.90	120.02
2.15	2.074	4.35	12.07	6.55	33.60	8.75	69.30	10.95	121.41
2.20	2.196	4.40	12.42	6.60	34.24	8.80	70.30	11.00	122.81
2.25	2.323	4.45	12.78	6.65	34.89	8.85	71.30	11.05	124.21
2.30	2.455	4.50	13.14	6.70	35.56	8.90	72.31	11.10	125.61
2.35	2.590	4.55	13.51	6.75	36.23	8.95	73.33	11.15	127.03
2.40	2.730	4.60	13.89	6.80	36.89	9.00	74.36	11.20	128.45
2.45	2.875	4.65	14.27	6.85	37.58	9.05	75.40	11.25	129 90
2.50	3.024	4.70	14.65	6.90	38.27	9.10	76 44	11.30	131.35
2.55	3.177	4.75	15.04	6.95	38.96	9.15	77.49	11.35	132.81
2.60	3.335	4.80	15.44	7.00	39.67	9.20	78.55	11.40	134.27
2.65	3.498	4.85	15.85	7.05	40.38	9.25	79.63	11.45	135.75
2.70	3.666	4.90	16.26	7.10	41.10	9.30	80.71	11.50	137.23
2.75	3.838	4.95	16.68	7.15	41.83	9.35	81.80	11.55	138.73
2.80	4 014	5.00	17.11	7.20	42.56	9.40	82.90	11.60	140.23
2.85	4.196	5.05	17.54	7.25	43.30	9.45	84.01	11.65	141.75
2.90	4.382	5.10	17.97	7.30	44.06	9.50	85.12	11.70	143.28
2.95	4.574	5.15	18.42	7.35	44.82	9.55	86.24	11.75	144.82
3.00	4.770	5.20	18.87	7.40	45.58	9.60	87.37	11.80	146.36
3.05	4.971	5.25	19.32	7.45	46.36	9.65	88.52	11.85	147.91
3.10	5.178	5.30	19.79	7.50	47.14	9.70	89.67	11.90	149.48
3.15	5.388	5.35	20.26	7.55	47.92	9.75	90.83	11.95	151.05
3.20	5.605	5.40	20.73	7.60	48.72	9.80	92.00	12.00	152.64

1 cubic foot = 7.48 U. S. gals.; 1 U. S. gal. = 8.34 pounds.

TABLE VIII.

Coefficients of Discharge for Rectangular Orifices in thin vertical partitions with greater dimension horizontal.

From Fanning's Treatise on "Water-Supply Engineering."

Head upon centre of Orifice, Feet.	Breadth and Height of Orifices.			
	0.75 foot high. 1 foot wide.	0.50 foot high. 1 foot wide.	0.25 foot high. 1 foot wide.	0.125 foot high. 1 foot wide.
0.2	....	....	....	.6333
0.3	....	....	.6293	.6334
0.4	....	.6140	.6306	.6334
0.5	.6050	.6150	.6313	.6333
0.6	.6063	.6156	.6317	.6332
0.7	.6074	.6162	.6319	.6328
0.8	.6082	.6165	.6322	.6326
0.9	.6086	.6168	.6323	.6324
1.00	.6090	.6172	.6320	.6320
1.25	.6095	.6173	.6317	.6312
1.50	.6100	.6172	.6313	.6303
1.75	.6103	.6168	.6307	.6296
2.00	.6104	.6166	.6302	.6291
2.25	.6103	.6163	.6293	.6286
2.50	.6102	.6157	.6282	.6278
2.75	.6101	.6155	.6274	.6273
3.00	.6100	.6153	.6267	.6267
3.50	.6094	.6146	.6254	.6254
4.00	.6085	.6136	.6236	.6236
4.50	.6074	.6125	.6222	.6222
5.	.6063	.6114	.6202	.6202
6.	.6044	.6087	.6154	.6154
7.	.6032	.6058	.6110	.6114
8.	.6022	.6033	.6073	.6087
9.	.6015	.6020	.6045	.6070
10.	.6010	.6010	.6030	.6060
15.	.6012	.6013	.6033	.6066
20.	.6014	.6018	.6036	.6074
25.	.6016	.6022	.6040	.6083
30.	.6018	.6027	.6044	.6092
35.	.6022	.6032	.6049	.6103
40.	.6026	.6037	.6055	.6114
45.	.6030	.6043	.6062	.6125
50.	.6035	.6050	.6070	.6140

again that above the top, and varies from 4½ inches to 12 inches above the centre of the aperture.

The Smartsville inch is calculated from a discharge through a four-inch orifice with a seven-inch board top; that is to say, the head is seven inches above the opening, or nine inches above the centre. The bottom of the aperture is on a level with the bottom of the box, and the board which regulates the pressure is a plank one inch thick and seven inches deep. Thus an opening two hundred and fifty inches long and four inches wide, with a pressure of seven inches above the top of the orifice, will discharge 1000 Smartsville miner's inches. Each square inch of the opening will discharge 1.76 cubic feet per minute, which approximates the discharge per inch of a two-inch orifice through a three-inch plank with a head of nine inches above the centre of the opening, the said discharge being 1.78 cubic feet per minute. The Smartsville miner's inch will discharge 2534.40 cubic feet in twenty-four hours, though in that district the inch is reckoned for eleven hours only.

Other Inches.—The miner's inch of the Park Canal and Mining Company, in El Dorado County, discharges 1.39* cubic feet of water per minute. The inch of the South Yuba Canal Company is computed from a discharge through a two-inch aperture, over a one and one-half inch plank, with a head of six inches above the centre of the orifice.

At the North Bloomfield, Milton, and La Grange mines the inch has been calculated from a discharge through an opening fifty inches long and two inches wide, through a three-inch plank (outer inch chamfered), with the water seven inches above the centre of the opening.

Determination of the Inch; Experiments at Columbia Hill.—To determine the value of this miner's inch, a series of experiments was made at Columbia Hill,

* Estimated by J. J. Crawford, M.E.

latitude 39° N., elevation 2,900 feet above the sea-level. The *module* used was a rectangular slit fifty inches long and two inches wide, with head seven inches above the centre of the opening. The discharge was over a three-inch plank, the outer inch chamfered, as shown in Fig. 8. The size of the opening was taken with a measure (micrometer attached) which had been compared with and adjusted to a standard United States yard. Time was read to one-fifth of a second; the level of the water (drawn from a large reservoir) was determined with Boyden's hook, micrometer adjustment. The following results were obtained:

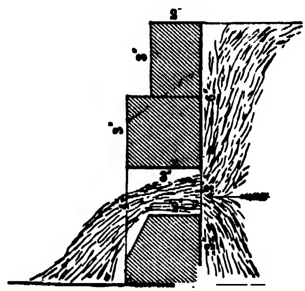


FIG. 8.

One miner's inch will discharge in 1 second...........	.026	cubic feet.
" " " " 1 minute...........	1.57	"
" " " " 1 hour	94.2	"
" " " " 24 hours............	2260 8	"

The coefficient of efflux is 61.6 per cent. These figures are within the limit of $\frac{1}{500}$ possible error.*

As the two-inch aperture requires too much space for gauging large quantities of water, custom has changed the form of the module, and an aperture twelve inches high by twelve and three-quarter inches wide, through a one and one-half inch plank, with a head of six inches above the top of the discharge, is now used. These openings discharge what is accepted as 200 miner's inches.

A series of experiments was made at La Grange, Stanislaus County, California, latitude 37° 41′ N., elevation 216 feet above the level of the sea, to determine the value of the inch thus delivered in the claims. The results here given are the mean of a series of gaugings

* The experiments were made in 1874 by H. Smith, Jr., C.E.

taken from nine different apertures, discharging in the aggregate 1,800 miner's inches.

The water was drawn directly from a flume and discharged into a small reservoir, across the lower end of which was fitted a gauge. The velocity of the water issuing from the flume was broken by several drops as it entered the reservoir, and the gauge at the lower end was raised sufficiently to prevent any flow due to an increased velocity which might have been acquired in the flume.

The level of the water was determined with a Boyaen's hook.

The discharge from the module was caught in a flume and conducted to a box fitted and levelled for the purpose. Time was read to one-fifth of a second. The following results were obtained:

One miner's inch	discharged	in	1 second...	.02499	cubic feet.
"	"	"	" 1 minute............	1.4994	"
"	"	"	" 1 hour..............	89.9640	"
"	"	"	" 24 hours...........	2159.1460	"

Effective coefficient of efflux, 59.05 per cent.*

An experiment on a single aperture of this form, made by Hamilton Smith, Jr., gave a discharge of 2179.4 cubic feet per miner's inch in twenty-four hours. The 2,230 cubic feet of the North Bloomfield inch can only be considered an assumed rough estimate of discharge in twenty-four hours for one miner's inch.

The theoretical velocity, in feet per second, of a fluid flowing into the air, through openings in the bottoms or sides of a vessel or reservoir, the surface level of which is kept constantly at the same height, is equal to that which a heavy body would acquire in falling through a space equal to the depth of the opening below the surface of the fluid, and is expressed as follows:

* The experiments were made by the author.

$$v = \sqrt{2gh}$$

In which v=velocity in feet per second.
g=the acceleration of gravity.
h=the height fallen in feet.

This is called Torricelli's theorem, which supposes indefinitely small orifices with thin sides, and assumes that the upper surface of the water and the orifices are under the same conditions as regards atmospheric pressure. Conditions and size of sectional area of the aperture, friction, resistance of the air to motion, and pressure of the atmosphere are all neglected.

The value of g varies in different latitudes, but for all practical purposes is taken as equal to 32.2.

$$\text{The theoretical head} = \frac{v^2}{2g}$$

The acceleration of gravity at latitude 45°=32.17 feet per second, being represented by g; for any other latitude, l.

$$g' = g\,(1 - 0.002588 \cos 2l)\,*$$

If g represents the acceleration of gravity at the height h, and r the radius of the earth, the acceleration of gravity at the level of the sea equals

$$g' = g\left(1 + \frac{2h}{r}\right)$$

Flow of Water in Open Channels.—There is no generally accepted formula for determining the velocity of water in open channels. The tables based on the old formulas published prior to the works of D'Arcy and Bazin in France, and of Humphreys and Abbot in the United States, being founded on data which ignored the important factor of the nature of the bed and the sides of the channel, have proved unsatisfactory. Hydraulic en-

* See professional papers, Corps of Engineers U. S. A., No. 12, page 26.

gineers have been compelled to rely for correctness of calculated results on the application of a combination of a few known laws with experimental data, which latter, though all-important, have been too restricted for the deduction of a reliable mathematical theory.

The formulas, in terms of dimensions of cross section and slope, are based upon the supposition of either "permanent" or "uniform" motion. Permanent motion approaches the condition of streams, permits changes of cross section and slope of the water-surface, excepting sudden bends, causing eddies and undulations, but demands that the discharge from the different sections should be identical. Uniform motion, in addition, requires an invariable cross section and constant slope of the fluid-surface. The general formulas based on permanent motion differ from those restricted to uniform motion, "by taking into account changes of living force produced by changes of cross section at the different points." * If there are no variations, the difference between the formulas disappears.

Chezy considered that the resistances encountered by water in uniform motion were in direct proportion to the length of the wetted perimeter, to the length of the channel, and to the square of the mean velocity; from which he deduced the formula,

$$v = c\sqrt{rs}$$

v is the mean velocity in feet per second.
c a coefficient taken at a constant value.
r the mean hydraulic radius in feet.
s the fall of surface in a unit of length.

The equation indicates the relation of the mean velocity to the slope and the mean hydraulic radius. The value of the coefficient c has been empirically demonstrated to

* Humphreys and Abbot, Mississippi Report, p. 207.

have a wide range. This formula, however, has been considered the simplest, and has been used by many engineers, different values being given to c, varying from 84 to 100 for large streams, and being as low as 68 for small streams. "Though there is abundant evidence," says Higham (p. 5), "that the latter is much too high for low values of v in earthen channels, and that 100 is too low for very large rivers, as high a value as 254.4 having been deduced from the Mississippi observations."

D'Arcy and Bazin, by their experiments on channels of moderate section with limited variation of grades, proved that the coefficient c involved not only r and s, but also a constant for the different degrees of roughness of the channel, the formula being applicable within certain limits of inclination and values of r.

Humphreys and Abbot make the velocity vary with the fourth root of the inclination, while Hagen assumes the velocity to vary with the sixth root.

Ganguillet and Kutter considered that the Chezy formula, $v=c\sqrt{rs}$, was the correct point of departure, but that the coefficient should be made variable, involving not only r and s, but likewise a constant for different degrees of roughness in the bed or channel.

The final formula adopted by Ganguillet and Kutter, which within certain limits of inclination, and especially in regular channels, will give very satisfactory results, is the following:

$$v=\left\{\frac{41.6+\frac{1.811}{N}+\frac{0.00281}{s}}{1.+\left(41.6+\frac{0.00281}{s}\right)\times\frac{N}{\sqrt{r}}}\right\}\sqrt{rs}$$

The coefficient of roughness, N, is dependent on the nature of the beds and sides. The useful values of this coefficient are as follows:

Nature of Sides of Channel.	Coefficient of Roughness.
Well planed timber	N=0.009
Plaster in pure cement	0.010
" " cement one-third sand	0.011
Unplaned timber	0.012
Ashlar and brick work	0.013
Canvas lining on frames	0.015
Rubble	0.017
Canals in very firm gravel	0.020
Rivers and canals in perfect order and regimen, and perfectly free from stones and weeds	0.025
Rivers and canals in moderately good order and regimen, having stones and weeds occasionally	0.030
Rivers and canals in bad order and regimen, overgrown with vegetation and strewn with stones or detritus of any sort	0.035
Torrential streams encumbered with detritus	0.050

Ditches in California.—In the mining districts of California ditches are constructed boldly, with steep grades and on irregular lines with numerous sharp curves. The cross sections, originally uniform, become more or less varied. Absorption, percolation, evaporation, and leakage reduce the flow. A distinct, reliable factor for each of these sources of loss cannot well be incorporated in the coefficient of discharge. If, then, it is intended to cover all of these common sources of loss by such a coefficient, its value must be a material modification of values commonly given in the text books. It would be certainly an affectation of accuracy to apply so complicated a formula as that of Kutter in such a case, since the modifying conditions, which can be estimated but roughly, call for a large reduction of the calculated result. This will be apparent from the measurements of discharge given further on. The simple formula, $Q = ac\sqrt{rs}$, expresses more fitly the result of experience in such cases, wherein—

Q is the quantity of water which the ditch is capable of carrying in cubic feet per second.

a the effective area of cross section of ditch, as originally constructed, in square feet.

r the hydraulic mean depth in feet.
s the fall of surface in a unit of length.
c a coefficient covering all common losses.

Examples of Value of Coefficient in Ditches.—In its application to the North Bloomfield main ditch* (length 40 miles, sectional area 23.89 square feet, grade 16 feet per mile), with its abrupt turns and sinuous course, the value of the coefficient c, as determined, varies from 44.7 to 37.7 in accordance with the season of the year.

The Texas Creek † branch ditch is about seven-tenths of a mile long. Its sectional area is 13.5 feet and the grade is 20 feet per mile. The sides are rough and the curves are sharp. With a flow of 32.8 cubic feet per second, the ditch runs about full. The value of $c = 33$. In connection with this ditch there is a rectangular flume 2.67 feet wide × 2.83 feet deep, made of unplaned boards, set on a grade of 32 feet per mile. The flume has some sharp but regular curves, and the water from the ditch runs it nearly full at these points. With the discharge 32.8 cubic feet per second, $c = 59$.

On the Milton line, from Milton to Eureka, a distance of 19.4 miles, the sectional area of the ditch is 20.39 square feet, grade 19.2 feet per mile for the earthwork and 32 feet per mile for flume. The line is very irregular, having many drops and chutes. The distance from Milton to the measuring box at Bloody Run is 29½ miles. The minimum established grade for the last 10.1 miles was 16 feet per mile, with a sectional area for the ditch of 23.05 square feet. The coefficient c, determined from the gauging at the measuring box, has varied from 22 in its leakiest condition to 31, which latter can be taken as correct for the present condition. In the succeeding 30 miles below the gauge, owing to a better character of ground, the coefficient reaches 41.

* Increased capacity of this ditch is limited by the pipes across Humbug Cañon.

† For details of Texas Creek ditch and flume see paper by Hamilton Smith, Jr., "Transactions Am. Soc. C.E.," vol. xiii. pp. 30–31.

The La Grange main ditch, 17 miles long, has a sectional area of 22.5 square feet, and a grade of 7 feet per mile. From the delivery, 56.5 cubic feet per second, at its Patricksville junction the coefficient c is determined to be 52, but it is based upon the assumption that the depth of the canal is 3 feet, whereas in the original construction it was supposed to have been made 4 feet deep; the discharge therefore due to such a sectional area would necessarily diminish the ascribed value of c.*

In all these canals, after the artificial banks are well consolidated, the water area is increased beyond the original excavation in the natural ground.

Accuracy cannot be expected in calculating the values of Q for proposed ditches of such character. Important losses must vary in every ditch, depending on the nature of the ground, and the character of the construction of the work, and the season of the year. The feeders along the lines largely compensate for these losses. In order to be safe in estimating the capacity of a ditch, the value of the coefficient c for the dry season should be taken.

The following facts show the magnitude of the losses due to absorption, leakage, evaporation, etc.

Three thousand miner's inches of water (a flow of 75 cubic feet per second) turned in during the dry season at the head of the Bloomfield ditch will deliver 2,700 inches (67.5 cubic feet per second) at the gauge 40 miles distant. 2,400 inches of water (60 cubic feet per second) turned in at the head of the Milton ditch formerly delivered at the gauge, 29½ miles distant, 1,450 to 1,600 inches (36.25 to 40 cubic feet per second); but at present 2,500 inches (62.5 cubic feet per second) turned into the head of the ditch delivers 2,000 inches (50 cubic feet per second) at the gauge. The exact loss of water between the head of this ditch and the measuring box is shown in the following

* The grades given in all the above cases, from which the different values of c were calculated, are otherwise independent of the drops, chutes, flumes, etc. Sectional areas represent minimum cross sections.

summary, taken from the official records for the month of August for the years 1875 to 1882 inclusive. This month is taken as a dry month, as prior to that time the numerous side streams swell the amount delivered at the gauge:

RECORD FOR AUGUST.

Year.	Water turned in at Milton, 24-hour inches.	—Water record at Bloody Run.— 24-hour inches.	Per cent.
1875	44,000	34,950	79.4
1876	59,700	42,625	71.3
1877	67,875	44,700	65.9
1878	76,050	58,875	77.4
1879	82,725	51,350	62.0
1880	74,080	55,325	74.7
1881	66,850	48,325	72.3
1882	68,300	50,984	74.4

The Eureka Lake ditch, with 2,500 inches turned in at the head, delivers at the gauge, 33 miles distant, about 1,800 inches in the dry season.

The above statistics lead to the adoption of values of the co-efficient c, varying from 31 to 45, in estimating the capacity of ditches* on heavy grades of forty miles length flowing from sixty to eighty cubic feet per second, such as referred to—that is:

$$Q = 31 \text{ to } 45\ a \sqrt{rs}$$

The loss incurred in the distribution of water is denoted by the following figures, taken from the official records of two mining companies. The amount received is measured at or near the distributing reservoirs; the amount used, at or near the pressure boxes. The difference shows the losses from leakage, evaporation, absorption, and wastage arising from excess of constant supply over the amount needed, with interruptions at the claim:

* These ditches are constructed on the rough mountain sides in rock more or less disintegrated.

NORTH BLOOMFIELD COMPANY (24-HOUR INCHES).

Year.	Amount Received.	Amount Used.	Loss.
1870 to 1879, incl..	5,838,865	5,504,758	334,107=6 per cent.
1880.............	945.550	920,612	24,938=2½ "
1881*............	950,340	866,962	83,378=9 "
1882.............	1,025,880	1,005,977	19,903=2 "
1883.............	862,660	836,251	26,409=3 "
14 years..........	9,623,295	9,134,560	488,735=5 per cent.

MILTON COMPANY (24-HOUR INCHES).

Year.	Amount Received.	Amount Used.	Loss.
1882.............	685,933	635,884	50,049= 7 per cent.
1883†............	446,224	361,877	84,347=19 "
2 years...........	1,132,157	997,761	134,396=13 per cent.

*Much water ran to waste during four months, owing to cessation of work caused by litigation.

† English reservoir, from which source the main water-supply was obtained, was destroyed June 18, 1883.

CHAPTER X.

DITCHES AND FLUMES.

DITCHES.

The demand for water throughout the mining districts has caused the construction of thousands of miles of ditches. The cost of these has been immense, but the returns on legitimate enterprises have well repaid the capital invested. On account of the rugged character of the country traversed by the ditch lines, in order to lessen the cost and expedite the work, steep grades were used, high trestles were built (in some instances supporting large flumes at elevations of two hundred to two hundred and fifty feet), and wrought-iron pipes were introduced for conveying the water across the valleys and cañons. The boldness with which these works were undertaken was characteristic of their originators.

Location and Construction Principles.—In locating and constructing ditches the following rules should be observed:

(1) The source of supply should be at sufficient elevation to cover the greatest range of mining ground at the smallest expense, great hydrostatic pressure being always desirable.

(2) An abundant and permanent supply of water during the summer months should be secured.

(3) The snow line, when possible, should be avoided, and the ditch, especially in snow regions, located so as to have a southern exposure.

(4) All water-courses on the line of the ditch should be secured; their supply partially counteracts the loss by evaporation, leakage, and absorption, and frequently fur-

nishes an additional quantum of water during several months of the year.

(5) At proper intervals waste-gates should be arranged so as to discharge the water, when necessary, without risk of damage to the ditch. In regions of heavy snow these waste-ways should be provided at intervals not greater than one-half a mile.

(6) Ditches, when practicable and the cost not being excessive, should be preferred to flumes.

Surveying a Ditch Line.—In the preliminary examination for the location of a long ditch, by means of careful comparative observations made with good aneroid barometers, the elevations not only of the termini, but also of intermediate points from which different surveying parties can start on the subsequent location of the line, can be approximately determined.

The various necessary points once established by survey, the line is staked. In levelling, all turning points should be made on grade. The stations should be properly numbered and staked, and pegs driven to grade. Every four or five stations the rodman should be required to call off the reading of the rod, which is checked by the notes of the surveyors. Stations may be from fifty to one hundred feet apart on ordinary ground, but a very irregular country demands shorter intervals, sometimes of a rod only. Bench marks should be placed every one-fourth or one-half mile for convenient reference.

All details of tunnels, cuts, and depressions which require fluming or piping should be worked out in full. In this work the hand level can often be employed with advantage. Complete notes should be made of the character of the ground along the entire line, and also of any possible changes.

The size of a ditch is regulated by its requirements. Its form will be modified often by circumstances of which the engineer is the judge. The smallest section for any given discharge is when the hydraulic mean depth is one-

half of the actual depth. As a general proposition, this is the most economical form of profile for water-channels with given side slopes. The amount of excavation is the least in that channel where the wetted perimeter for a given area is the smallest. In practice the forms commonly adopted for ditches and flumes are trapezoidal and rectangular.

With rectangular profiles the resistance due to friction is the smallest when the width is twice the height.

Of trapezoidal profiles, the half of a regular hexagon is generally used in canals and ditches.

Circular and square profiles are employed only in stone, wood, and iron constructions.

Narrow and Deep *vs.* Broad and Shallow Ditches.—In a mountainous country narrow and deep ditches with steep grades will generally be found preferable to large conduits with gentler slopes. The first cost of excavation is much less, as is also the cost of repairs rendered necessary by snows and severe storms, the narrower aqueduct being more easily protected. The experience of the ditch-builders in this State has been uniformly favorable to these steep grades, but little trouble being caused by the washing of the banks due to high velocities. In the valleys with ashy soil such grades, of course, would not be practicable.

Ditches in California with carrying capacities as large as 80 cubic feet per second have been built, and are now in successful operation, with grades of sixteen to twenty feet per mile.

Excavating the Ditch.—Before the work of excavating is commenced the line is cleared of trees and underbrush for a sufficient width to render work afterwards easy and to prevent subsequent damage to the ditch. All trees which are liable to fall and injure the work should be removed before construction begins. On a flume line the brush for at least ten feet on each side is burned as a precaution against fire. So far as possible, and especially

along a side hill, the ditch should be dug so as to have walls of solid, untouched ground, and not made banks. The top of the solid bank on the lower side should be fully three feet wide. In such cases the top soil is first removed for the width of the ditch and bank; the material excavated to form the ditch is used to raise the lower bank, and in time consolidates to firm ground, thus increasing the capacity of the ditch.

The digging of ditches is usually let by contract at a given sum per rod, and heavy cuts per cubic yard. It is customary to excavate large ditches with a slope of 60° for the upper and 65° for the lower bank. These slopes, of course, the engineer will vary in accordance with the ground encountered. In practice they are changed eventually by erosion and denudation; but experience seems to warrant the above-mentioned slopes as the best to be adopted in laying out such works.

In large mining ditches constructed with high grades and running large amounts of water, the erosion and consequent enlargement of the ditch (when kept in order) is noticeable; moreover, the banks gradually become solidified, and thereby the loss by leakage and absorption is decreased. It is roughly estimated that the capacity of a well-constructed ditch which is properly kept up is increased about 10 per cent. in eight years.

Ditches poorly built in the beginning subsequently require large and constant expenditures, and lose considerable amounts of water. The annual cost of running and maintaining large ditches, including all repairs and taxes, is estimated to be $400 per mile.

Examples of Ditches.—Among the principal ditches in the State are the North Bloomfield, the Milton, the Eureka Lake, the San Juan, the South Yuba Canal, the Excelsior or China ditch, the Bouyer, the Union, the El Dorado, the Spring Valley and Cherokee, the Hendricks and the La Grange.

North Bloomfield.—The North Bloomfield main

ditch, including distributers, is fifty-five miles long. Its size is 8.65 feet on top, 5 feet at bottom, and 3½ feet deep. The ditch and distributers cost $466,707. Its grade is sixteen feet per mile, discharging 3,200 miner's inches.

Milton Company.—The Milton Company's ditches are eighty-four miles long, and their grades are from twelve to thirty-two feet to the mile. The size of the main ditch is 4 feet on the bottom, 7.6 feet on top, and 3½ feet deep, discharging 3,000 miner's inches; cost, $462,998.

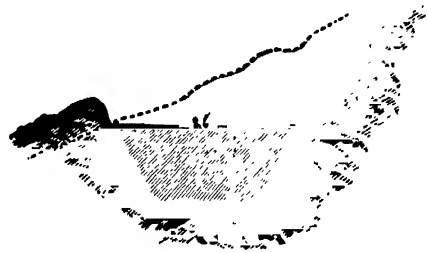


FIG. 9. NORTH BLOOMFIELD MAIN DITCH. GRADE, 16 FT. PER MILE. SEC., 23.89 SQ. FT.

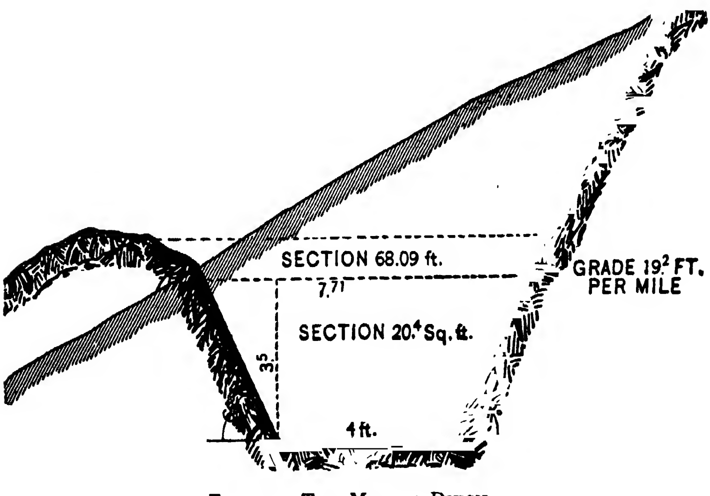


FIG. 10. THE MILTON DITCH.

Eureka Lake.—The Eureka Lake main ditch is eighteen miles long and has a capacity of 2,500 miner's

inches. Its cost, including water rights and flumes, was \$256,000. The San Juan ditch and branches extend some forty-five miles in length; the main ditch is thirty-two miles long, and its capacity is 1,300 miner's inches. The cost was \$292,992. These two last mentioned ditches belong to the Eureka Lake and Yuba Canal Company.

South Yuba Canal Company.—The main ditch of the South Yuba Canal Company (from the head of Bear River) is one and one-half miles long, six feet wide on top, and five feet deep, with a grade of thirteen feet per mile. Its present capacity is said to be 7,000 miner's inches. From Bear Valley (the junction of the main and the Dutch Flat ditches) the size of the canal for the succeeding thirty-one and one-half miles is six feet wide on top, four and one-half feet deep, with a grade of eight feet to the mile. The Dutch Flat ditch is thirteen miles long; it is six and one-half feet wide on top, four feet deep, and has a grade of thirteen and one-half feet per mile. The capacity of this ditch is 3,150 miner's inches. The Chalk Bluff ditch is six feet wide on top and five feet deep, with a grade of sixteen feet per mile, and has a capacity of 4,100 miner's inches. The several ditches owned by the South Yuba Company have an aggregate length of one hundred and twenty-eight miles.

Smartsville Ditches.—The Excelsior, or China, ditch at Smartsville is thirty-three miles long, five feet wide at the bottom and eight feet on top, and is four feet deep. The grade is nine feet to the mile, and the ditch discharges 1,700 Smartsville miner's inches.

The Bouyer and Union ditches are each about fifteen miles long, four feet wide on the bottom, eight feet on top, and three and one-half feet deep. Their grades are thirteen feet to the mile, and each discharges 1,200 Smartsville miner's inches.

There are several minor ditches which deliver water in and around Smartsville. The total capacity of all these ditches is 5,000 Smartsville miner's inches, and the

whole investment in this class of property approximates $1,200,000.

Spring Valley.—The Spring Valley and Cherokee ditch is fifty-two miles long and has about four miles of iron pipe thirty inches in diameter. The size of the ditch averages five feet wide, three and one-half feet deep, discharging about 2,000 inches of water.

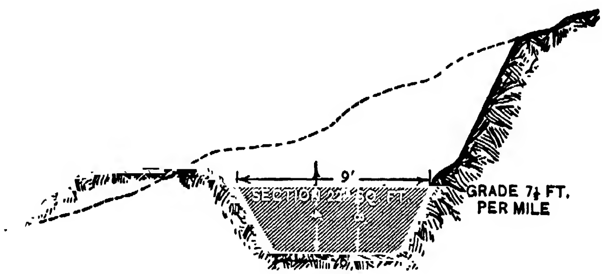


FIG. 11. LA GRANGE DITCH.

FIG. 12. SECTION OF WALL DITCH ON LINE OF LA GRANGE MINING COMPANY'S DITCH.

Hendricks.—The Hendricks ditch, in Butte County, is forty-six and one-half miles long; grade of the upper line of ditch, 12.8 feet per mile; grade of the lower line, 6.4 feet per mile; dimensions, 5 feet wide, 2 feet deep.

Total cost, including Glen Beatson ditch and Oregon Gulch ditch, $136,150.*

La Grange.—The La Grange ditch,† including the Patricksville branch, is over twenty miles in length. Size, nine feet on top, six feet at the bottom, four feet deep; grade, from seven to eight feet to the mile. The greater part of the ditch is cut in granite, and in places there are solid stone walls fifty to seventy feet high. It discharged 2,400 miner's inches at the date of last measurement, and its cost was over $450,000. Its capacity was formerly larger, but the ditch is now in a bad condition.

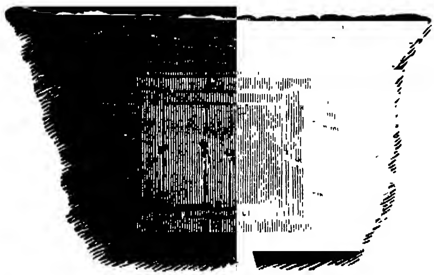


FIG. 13. LA GRANGE FLUME. CROSSING AT INDIAN BAR.

FLUMES.

In general, the use of flumes is to be avoided where-ever possible, long experience demonstrating that they are not economical, being too liable to destruction from fire, wind and snow storms, and by decay. Hence they are a source of continuous expense.

Flumes *vs.* Ditches.—There are instances where the formation of the country requires the use of flumes rather than ditches; for example, where the water must be conveyed along the face of vertical cliffs, as in the case of the Miocene Gold-Mining Company in Butte County. There are also certain conditions of the formation of the ground, independent of the topography, where a ditch cannot be employed so economically as a flume—viz., when the ground is composed of either very hard or very

* See Raymond's Report, 1873, pages 73 and 74.

† The original ditch, about nineteen miles long, is said to have cost $375,000. Since its completion the Patricksville ditch and reservoir have been built at a cost of $75,000.

porous and shattered material. Likewise where water is scarce and the evaporation and absorption are great, flumes must necessarily be preferred. In such cases as these either flumes or pipes may be advantageously used.

Grades.—Flumes are set, where practicable, on grades of twenty-five to thirty-five feet per mile, and are consequently of proportionately smaller area than ditches.

The annexed sketch shows the general style of constructing flumes.

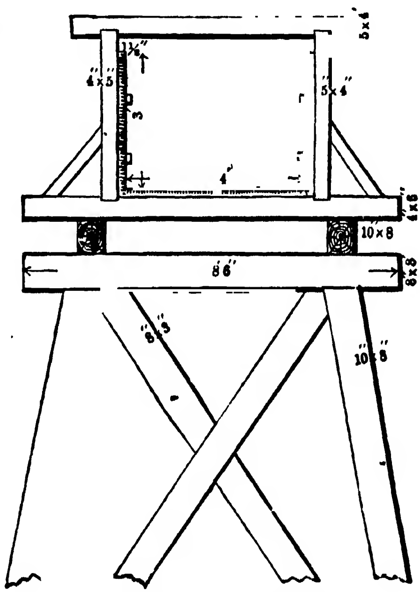


FIG. 14. FLUME CONSTRUCTION.

Planking.—The planking used ordinarily is of heart sugar pine (seasoned) one and one-half to two inches thick, twelve to twenty-four inches wide, according to the requirements, and twelve to sixteen feet long, the twelve-foot length being the most desirable.

Sills and Posts.—Where the boards join, pine battens three to four inches wide, one-half inch thick, cover the seams Sills, posts, and caps strengthen the structure every four feet. The dimensions of the timbers depend on the size of the flume. A flume two and one-half feet square requires 3×4 inch scantling for posts, caps, and sills, and 4×6 inch for the stringers; while a flume 4×3 feet in the clear should use 4×5 inch stuff for the caps and posts, sills 4×6 inches, with stringers 10×8 inches in size. These sizes are used in regions

of heavy snow, and can be reduced somewhat in milder localities.

The width of the flume regulates the length of the sills and caps, and the length of the posts is determined by the depth of the flume, three inches or less being allowed between the top of the planks and the cap. In larger flumes these different sizes are slightly increased.

The posts should be set into the caps and sills with a gain of one and one-fourth inch, and not mortised. The sills generally extend from twelve to twenty inches beyond the post (according to the size of the structure), and to them side braces are nailed to strengthen the structure, although these side braces are generally unnecessary in properly constructed flumes. In the mountain regions snow and ice frequently attach themselves to the braces and sills, breaking them off and occasionally destroying the flume. On top of the caps there is placed a foot plank eight to ten inches in width.

Flumes should be placed on a solid bed on the required grade. To avoid damage from slides, or snow and wind storms, the bed should be excavated in the bank of the side hills and the flume placed close to the bank. Stringers running the entire length of the flume are placed beneath the sills immediately outside of the posts. They are not absolutely necessary, but are desirable, as they preserve the sill timbers from decay.

Curves.—When curves are necessary they should be laid with great care, so as to insure the maximum flow of water. The boxes must be cut in two, three, or four parts, as the case may demand. This necessitates an increase in the number of sills, posts, and caps. To secure the better curving of the side planks they are sawed partially through in different places, so that they bend easily, the sawed portions closing thoroughly by the curving of the plank.

To distribute the water equally over the entire flume and prevent slack water, irregular currents, and splash-

ing, the outer side of the flume is raised in accordance with the curve. No rule can be given for the exact amount of rise, but it can be readily determined by wedging up the flume. This is very essential in cold climates, as ice forms where any splashing occurs.

Waste-Gates.—Waste-gates should be placed every half-mile, so that the water can be readily turned out, as may be required from time to time, and are especially necessary in case of any accident. They should discharge the water clear of the line to prevent any undermining. They are useful also for clearing the canal of snow and ice.

Precautions against Cold.—In the snow belt the flumes are covered with sheds in the most dangerous places where they are exposed to snow slides. The most approved form of snow shed consists of sets of timber 4×6 inches to 7×9 inches in size, placed at intervals of four feet and covered with boards or lagging. Where the flume is set in close to the bank the circulation of air around it during the winter is partially prevented by snow, and freezing of the water is not so probable as where the flume is exposed on all sides.

Great difficulty is experienced sometimes in keeping flumes and ditches open during long continued very cold weather, on account of the formation of anchor ice on the bottom. When this occurs it is necessary immediately to turn out the water, otherwise they will fill up solidly with ice and remain closed until spring. Should snow fill the flume when empty, it can be readily run out if the water is turned on before it is allowed to pack.

In Nevada County, at the head of the Bloomfield ditch, the snow falls in depths of from six to thirteen feet on a level. The temperature ranges as low as zero, but ordinarily has a winter mean of 30° Fahr. The Bloomfield ditch, carrying 80 cubic feet of water per second, is seldom troubled by the forming of ice or snow blockades. This ditch is supplied from a reservoir, the water of

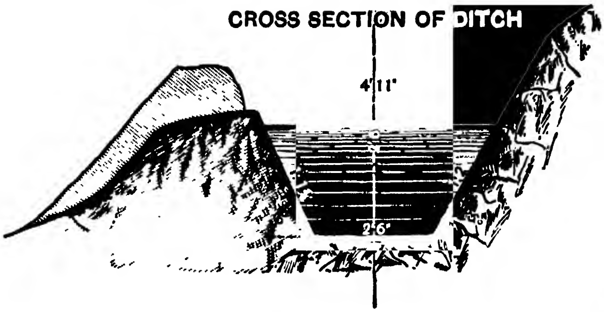
which is of a temperature of 36° Fahr. The canal for the first twenty miles collects but little snow even during heavy storms; in the lower twenty miles, the water having become more chilled, snow collects rapidly at times, and the ditch has upon a few occasions been blockaded.

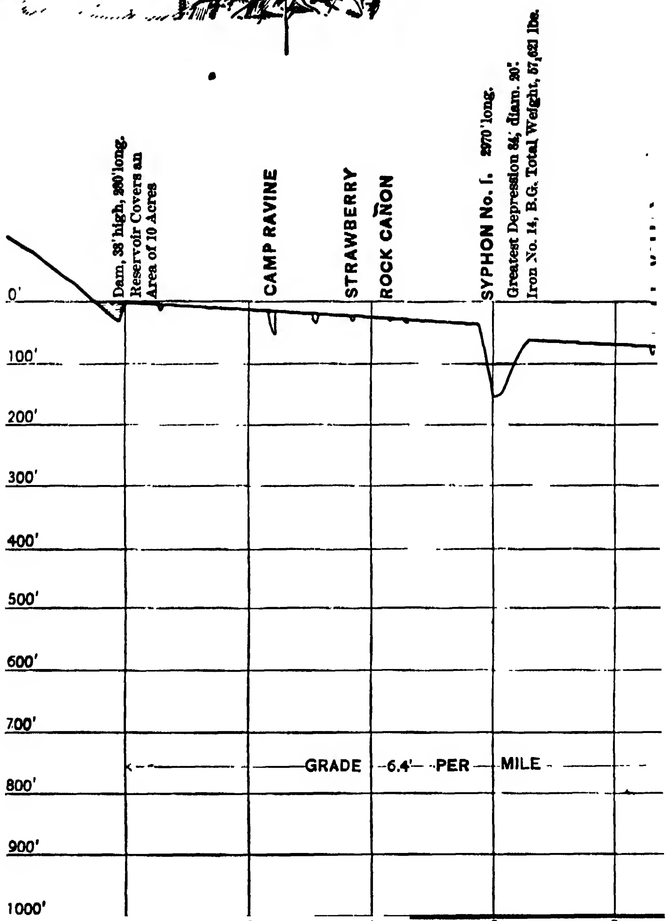
Other ditches in the same locality, of nearly equal capacity, but lying on the cold north hillsides and drawing water from creeks and rivers, have great difficulty in running water in cold, stormy winters, owing to the formation of ice, snow slides, and snow blockades.

The head of the Milton ditch being on the north side of a cold cañon, the temperature at times falls as low as −21° Fahr. Notwithstanding this excessive cold, the ditch is kept open the greater part of the winter when there is a sufficient supply of water, and with a flow of 80 cubic feet per second probably but little difficulty would be experienced in keeping up a constant supply.

Experience in the Black Hills.—In the winter of 1879–80, on the line of the Wyoming and Dakota Water Company's open flume, at the head of the Spearfish River in the Black Hills, Dakota, with the mercury ranging from 5° to 35° (Fahr.) below zero, no difficulty was experienced in running the water a distance of about six miles (the portion then finished) during the entire season, the temperature of the water varying from 42° to 35° Fahr.

On one occasion the thermometer reached 43° below zero, as indicated by the spirit thermometers; the mercurial thermometers bursting at −42° Fahr. The temperature of the water at this time fell to 35° Fahr. The extreme cold lasted but a few hours, still no ice formed in the flume. The water (a continuous flow of 350 cubic feet per minute) in the flume was drawn directly from the Spearfish River (supplied at the upper end by springs), which was at this season frozen over. The water did not freeze because the flume was well protected and set in close to the bank, thus allowing no circulation of air under the sills, the outer ends being covered with





Weights of Syphons do not include Weights of Rivets.

PROFILE OF THE

.RFISH DITCH.

CAPACITY.

Grade, 6.4' per mile, 750 m

" 10' " " 910

" 12.4' " " 1027

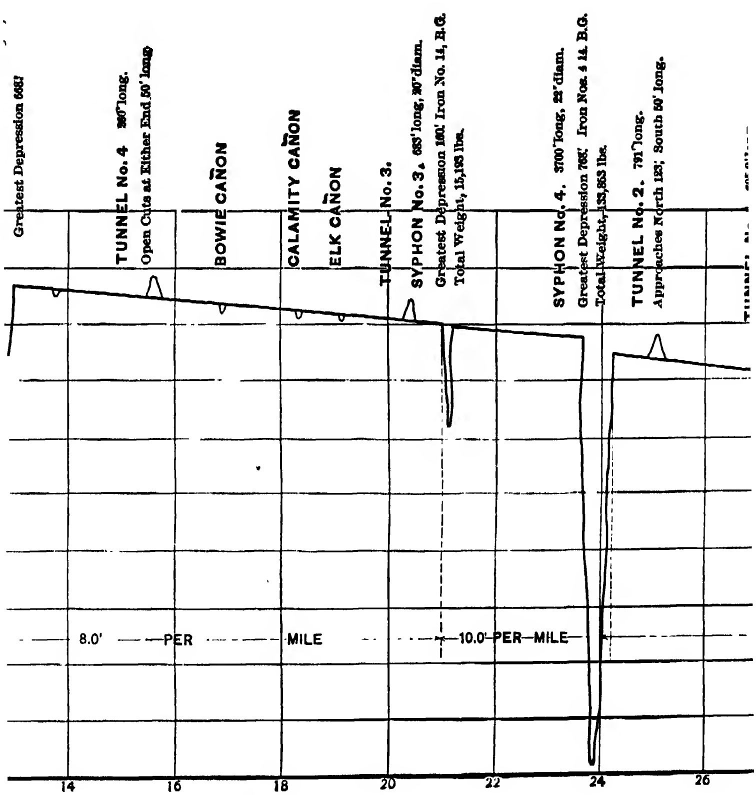
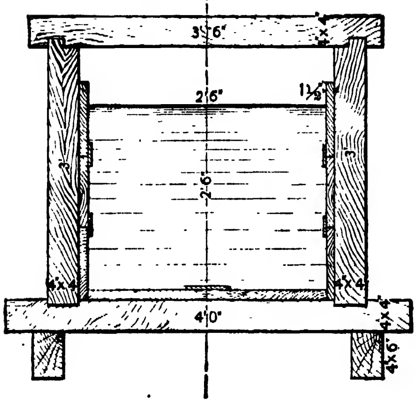
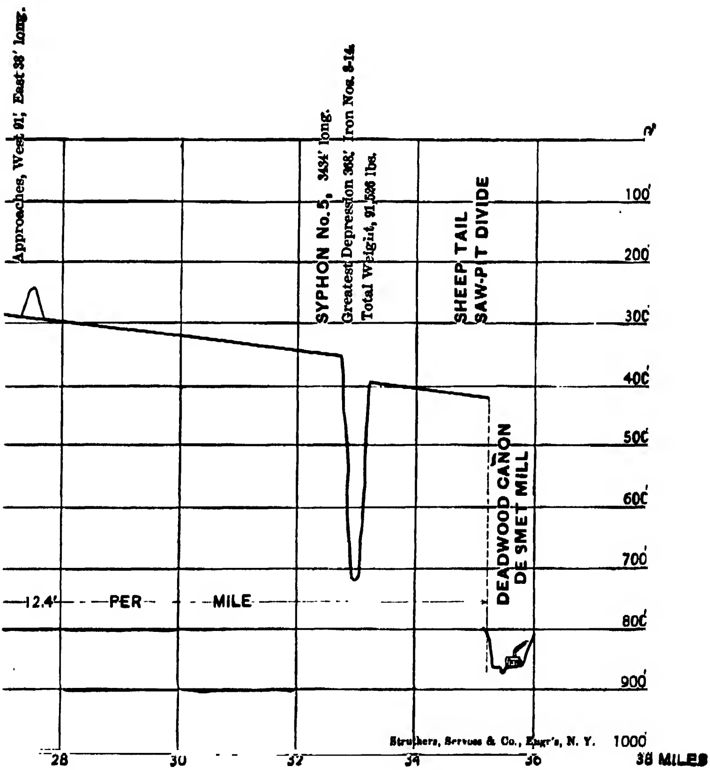


Fig. 15

Inch
"
"

CROSS SECTION OF FLUME





snow; the boxes were set to an exact grade and the curves were constructed carefully, so that along the entire line there was no splashing or slack water or irregular currents; and, furthermore, the water, coming from springs, was warm and the distance run was short.

The Wyoming and Dakota Water Company's main conduit from Spearfish was designed with the view of conveying water to the mining camps of Deadwood, Central, and Lead. The total length of the projected line to its main distributing point was thirty-five miles, consisting of twenty-six miles of flume (including a mile of tunnel and approaches); two and three-fourth miles of twenty-two-inch diameter wrought-iron pipe for inverted siphons, crossing depressions from thirty-four feet to seven hundred and sixty-eight feet; thirty-five hundred feet of trestle-work (the longest piece being three hundred and ninety feet long and seventy-five feet high), and the remaining portion of the line was to have been ditched. The capacity of the conduit was estimated at 1,000 twenty-four-hour miner's inches. The principal supply was to have been drawn from a reservoir at the head of the Spearfish River, and additional amounts were to have been obtained from seven different tributaries or feeders along the line of work.

Owing to conflicting interests and litigation this extensive work was never completed. The accompanying plan (Fig. 15) is a profile of the projected line, showing the grade, depressions, and work completed in 1879.

Details of Construction.—In constructing a line of flume, the bed being prepared, the stringers are put in place and the sills laid on them four feet apart. The bottom planks (the ends being sawed off square) are then nailed to the sills, the end joints being carefully fitted. The side planks are nailed to the bottom planks and to the posts, which last are set in a gain in the sills, an occasional cap in the beginning being placed on the posts to hold the flume in shape. The size of the nails for planks,

posts, and caps depends on the thickness of the material, sixteen-penny and twenty-penny nails being those generally used. The battens are securely fastened over the various joints or seams with six-penny nails. Each box as completed is carefully set on the established grade and firmly held in position with wooden wedges. The remaining caps are put on whenever convenient.

Where a flume connects with a ditch the posts for a distance of several boxes back are lengthened sufficiently to permit of the introduction of an additional plank on each side. The end boxes of the flume are flared, to permit a free entrance and discharge of the water. An outer siding, nailed to the posts, at the junction with a ditch, or wherever else a bank of earth is passed through, protects the flume and also strengthens it materially.

When large amounts of lumber are to be used, it is occasionally economical for a company to erect a portable saw-mill and cut out the lumber. In most cases, however, it is cheaper to contract for the material required.

All lumber should be inspected and measured by a competent scaler, whose duty it is to reject all knotty, sap, wind-shaken stuff, and slabs. As only dimension stuff is used, everything should be prepared at the mills of the exact sizes required, so that the flume can be constructed as rapidly as the material is received.

The material should be delivered at the head of the flume, or at such convenient places as the engineer may direct. Lumber stored should be carefully piled, and spaced so as to permit a free circulation of air through the material.

Sufficient water is generally obtained along the line of work, and is turned into the flume as fast as constructed, to assist in the delivery of the lumber which is floated. A few inches' depth of water is all that is necessary. One or two or more men are required to attend to the floating of the material, according to the distance.

As occasion may demand, the flume is trestled, the

main supports being placed every eight to twelve feet. The lumber, scantling, and struts for bents are used in accordance with the demands of the work. The foundations must be made secure to hold the superstructure, and no mortises used, heavy spikes and strong timber and braces being sufficient. Guy ropes are employed when necessary to prevent any vibration or movement of the flume caused by severe wind storms.

It is the usual practice to distribute along the line of a ditch and flume a certain amount of lumber, to be ready, in case of accident, for repairing any breaks. Breaks on ditch lines, especially during the winter, are repaired more easily with pieces of flume than with dirt. A supply of ten per cent. of lumber is not an excessive amount to have on hand. The life of a flume, under the best of circumstances and care, will not exceed twenty years, and generally not over half that time.

Lumber.—The following tables show the amount of lumber required in the construction of twelve-foot flume-boxes of different widths and depths:

TABLE IX.

Flume two and one-half feet wide, two and one-half feet deep; twelve-foot box.

3 Caps,	4 feet long ×	3 inches ×	4 inches	= 12 feet b.m.
6 Posts,	3 " " ×	3 " ×	4 "	= 18 " "
9 Planks,	12 " " ×	$1\frac{1}{2}$ " ×	{ 6 " / 12 "	= 135 " "
3 Sills,	$4\frac{1}{2}$ " " ×	4 " ×	4 "	= 18 " "
2 Stringers,	12 " " ×	4 " ×	6 "	= 48 " "
6 Battens,	12 " " ×	3 " ×	1 "	= 18 " "
1 Foot plank,	12 " " ×	10 " ×	$1\frac{1}{2}$ "	= 15 " "

Total lumber in one box .... 264 feet b.m.

Number of boxes per mile 440

TABLE X.

Flume four feet wide, three feet deep; twelve-foot box.

Planks,	2 inches thick, 12 feet long			....	=240 feet b.m.
6 Posts,	4 inches ×	5 inches ×	3 feet 9 inches long..		= 38 " "
3 Caps,	4 " ×	5 " ×	6 " long	....	= 30 " "
3 Sills,	4 " ×	6 " ×	8 " "	....	= 48 " "
2 Stringers,	8 " ×	10 " ×	12 " "	....	=160 " "
6 Battens,	3 " ×	1 " ×	12 " "	....	= 18 " "
1 Foot plank,	10 " ×	1½ " ×	12 " "	....	= 15 " "
Total lumber in one box				....	540 feet b.m.

TABLE XI.

Flume seven feet wide, four feet deep; twelve-foot box.

Planks,	1½ inches thick, 12 feet long			....	=270 feet b.m.
6 Posts,	4 inches ×	6 inches ×	4 feet 4 inches long.		= 52 " "
3 Caps,	4 " ×	6 " ×	9 " 4 " "		= 56 " "
3 Sills,	4 " ×	8 " ×	10 feet long	....	= 80 " "
2 Stringers,	8 " ×	12 " ×	12 " "	....	=192 " "
8 Battens,	3 " ×	1 " ×	12 " "	....	= 24 " "
1 Foot plank,	10 " ×	1½ " ×	12 " "	....	= 15 " "
Total lumber in one box				....	689 feet b.m.

Bracket Flume.—A novel method of carrying flumes along the face of precipitous cliffs has been designed by W. H. Bellows and adopted on the line of the Miocene Mining Company's ditch in Butte County, to avoid the construction of a trestle-work one hundred and eighty-six feet high.

The line of ditch was run some two hundred yards up the cañon, abutting against a perpendicular wall of basaltic rock, along the face of which, one hundred and eighteen feet above the bed of the ravine and two hundred and thirty-two feet below the top of the cliff, the flume was carried on brackets for a distance of four hundred and eighty-six feet. Fig. 16 gives a general view, and Fig. 17 shows the method of hanging the flume.

The brackets are made of T-rails of thirty-pound railroad iron bent into the form of an L. The longer arm,

Fig. 16. Bracket Flume of Miocene Mining Company's Ditch, Butte Co., Cal.

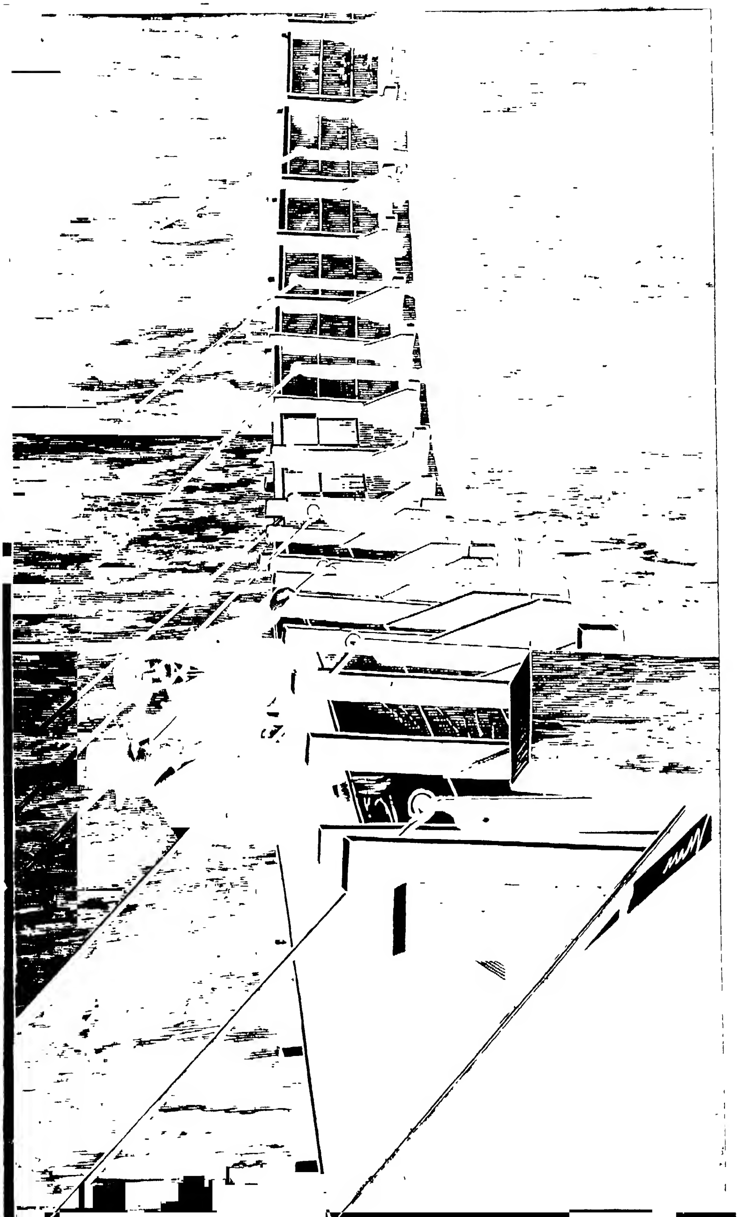


FIG. 17. METHOD OF HANGING FLUME TO CLIFF BY IRON BRACKETS.

ten feet long, is placed horizontally (for the bed of the flume to rest on), with its end supported in a hole drilled in the rock. The shorter arm, two feet long, stands vertically and has at its upper end an eye into which hooks a suspender of three-fourth-inch round iron, which in turn is fastened above to the rock by means of a ring-bolt soldered into a hole drilled for the purpose. The brackets are set eight feet apart, and were tested to sustain a weight of fourteen and one-half tons. The flume is four feet wide and three feet deep, inside measurements, and has a capacity of 3,000 miner's inches.

The general view shows a trestle eighty-six feet high. Along the line of the ditch there is a trestle one thousand and eighty-eight feet long and eighty feet high; another has been built one hundred and thirty-six feet high. The total length of ditch and flume is thirty-three and one-third miles.

Details and Costs of Milton Ditch and Flumes.—The following official statement shows the details and cost of construction of the Milton ditch and flumes from Eureka to Milton Dam.

Built by the North Bloomfield Gold-Mining Company in the years of 1872–3–4.

Lengths.

Eureka to South Fork	563 chains=	7.04 miles.
South Fork to Drop-off	96 " =	1 20 "
Drop-off to Milton	894 " =	11.17 "
Total	1,553 chains=	19.41 miles, =102,484 feet,

measured from head of Eureka drop-off to Milton dam.

Flumes.

Eureka to South Fork	961 twelve-foot boxes=say,	11,536 feet.
South Fork to Big Bluffs	264 " " " = "	3,168 "
Big Bluffs to Milton	1,113 " " " = "	13,352 "
Total	2,338 twelve-foot boxes=say,	28,056 feet.

The above 2,338 boxes include 56 boxes of flume built in the ditch, most of which is supported by heavy cribbing.

Waste-Ways.

Eureka to South Fork	14 wastes, aggregating	112 feet.
South Fork to Big Bluffs	12 "	"	48 "
Big Bluffs to Milton	24 "	"	114 "
Total	50 wastes, aggregating	274 feet.

There are also several branch flumes, one large crossing flume, and about one hundred and thirty feet of ditch lining.

TABLE XII.

Cost of Milton Ditch, from Milton to Eureka, 19.41 *miles.*

Excavation, etc.

	Distance.	Labor.	Explosives.	Tools.	Steel.	Coal.	Totals.
	Miles.						
Ditch	14.1	$69,664 92	$4,098 46	$1,606 67	$319 48	$953 38	$76,642 91
Flume Foundation	5.3	15,013 40	2.866 72	525 50	213 00	301 11	18,919 73
Clearing Line	19.4	3,582 01	....	90 00	...	....	3,672 01
	19.4	$88,260 33	$6,965 18	$2,222 17	$532 48	$1,254 49	$99,234 65

Flume.

Lumber, etc., Milton to lower end Big Bluffs	Feet. 1,083,434			
Less sold to Milton Company	200,000	Feet. 883,434		
Eureka to Big Bluffs, 1,225 boxes		765,911		
Total on hand and used for 2,338 boxes		1,649,345	$32,015 28	

Note.—Of the above amount of 883,434 feet it is supposed that there is on hand, say, 130,000 feet, thus leaving 750,000 feet as the amount used for 1,113 boxes from Milton to lower end of the bluffs.

Timbers cut by hand, stringers, posts, etc.	1,301 49	
Hauling timber to Milton, Little Poor Man's, etc	1,650 00	
		$34,966 77
Carry forward		$134,201 42

TABLE XII.—*continued.*

Brought forward........................$134,201 42

Carpenters, etc.

Gang.	Boxes 12 ft. long.	Labor.	Nails and Iron.	Tools.	Totals.	
Young.	1,145	$10,902 81	$1,499 57	$50 00	$12,452 38	
Marriott.....	1,193	10,497 90	1,559 57	50 00	12,107 47	
	2,338	$21,400 71	$3,059 14	$100 00	$24,559 85	$24,559 85

General Cost.

Surveys.—Engineer (who was also foreman) and assistants..................		$4,610 50	
Roads.—South Fork to Bowman's, 3¾ miles..........	$1,200 00		
South Fork to Little Poor Man's, 2¼ miles	200 00		
		1,400 00	
Hauling.—Transportation of tools, material, and men		1,450 94	
Boarding.—Loss in boarding laborers, who were charged 75 cents per day........		685 75	
General Expense.—Being a portion of North Bloomfield Gravel-Mining Company's cost of management, office, taxes, etc., while ditch was being built...........		3,564 63	
			11,711 82

Damages.

Eureka Lake Company—damage to it by breaking its miner's ditch by blasts.........................	1,635 87
Total cost..............................	$172,108 96
Collected from Milton Company for account extra work	689 30
Leaving Milton Ditch account (November 10, 1874) on Company's books.........................	$171,419 66

Note.—If the 130,000 feet of lumber supposed to be at Milton is sold for cost ($20 per thousand), the total cost of the ditch will be reduced to $169,508 96, or, say, $8,700 per mile. In that event—

Cost per foot, etc.

Ditch.—74,442 feet long, cost for, say, 117,600 cubic yards, $76,642 91, or 65 cents per cubic yard, or $1 03 per lin. foot.

Flume.—28,056 feet long, cost for excavation $18,919 73, or 67 cents per lin. foot.... cost for lumber, labor, etc., $59,526 62, or $2 12 per lin. foot....	$2 79 per lin. foot.

The ditch is graded in from slope pegs from 6 to 36

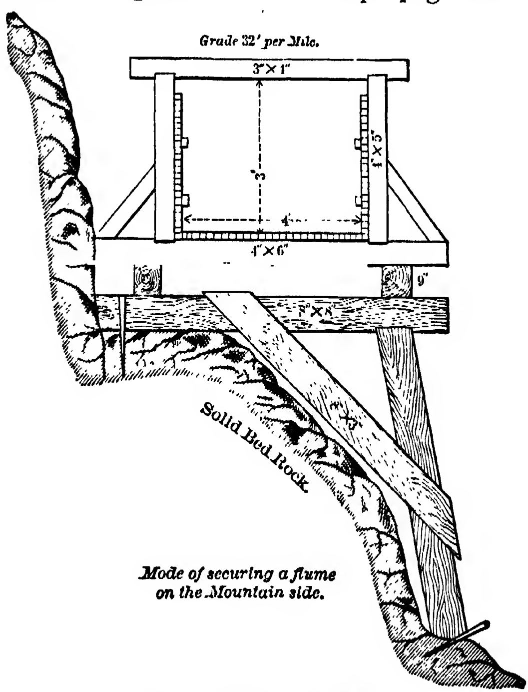


FIG. 18. MILTON FLUME.

inches. The general grade is 19.2 feet per mile. All trees within 15 to 25 feet of the edge of the upper bank are cut.

The logs, brush, and leaves from the lower bank (under the artificial bank) are carefully removed. The foundation is generally cut for the entire width of the flume. The sketch (Fig. 18) shows the method of posting along cliffs, where the foundation is occasionally narrower than the flume. Where flumes connect with the ditch, the posts of the flumes, for a distance of several boxes, are 4 to 4½ feet high, allowing an additional side plank. The grade of the flume is 32 feet per mile. The planking is 2 inches thick.

CHAPTER XI.

PIPES AND NOZZLES.

Wrought-Iron Pipes.—Wrought-iron pipe is used extensively in California on account of its cheapness of construction, its adaptability for crossing depressions, the facility with which it can be moved (changes of the position of the line being often necessary), and other advantages arising from its lightness combined with great tensile strength.

It is used as—

(1) A water-conduit, replacing ditches and flumes. Where large depressions are crossed it is called an "inverted siphon."

(2) A "supply or feed pipe," conveying water from the "pressure box" to the claim.

(3) A "distributing pipe," taking the water from the "distributer," or "gates," at the end of the supply pipe, and delivering it to

(4) the "discharge pipe" or "nozzle."

Large mining companies often have their pipes constructed at their own workshops, although generally the iron plates of proper size and thickness are punched and rolled before delivery, and put together on the claim.

Inverted Siphons.—According to Father Secchi, there is near the town of Alatri, in Italy, an "inverted siphon" with a depression of three hundred and thirty-eight feet, supposed to have been constructed by the Romans two hundred years before Christ. The pipes

are of earthenware, embedded in concrete, and are said to be still in a good state of preservation. There is, therefore, no novelty in the construction of this kind of water-conduit; but the use of wrought-iron pipe for this purpose was very limited until adopted in California, where it has been very largely employed, and where there have been obtained valuable data of the strength of materials and methods of construction, as well as of the flow of water through long pipes, essentially modifying theories and formulas previously accepted.

Thickness of Iron.—The thickness of the iron is determined by the pressure of the water and the diameter of the pipe, allowance being made, of course, for the quality of the material and the method of riveting. The factor of safety against damage from accident is regulated by the importance of the line. On account of variations in plates marked as being of the same size and number, it would be well, as a precautionary measure, to

TABLE XIV.

Thickness and Weight of the Principal Sizes of Iron used for Hydraulic Pipe.

No. B. G.	Thickness.—Inches.	Weight per sq. ft.—Pounds.	No. B. G.	Thickness.—Inches.	Weight per sq. ft.—Pounds.
18	.049	1.98	6	.203	8.20
16	$\frac{1}{16}+=.065$	2.62	4	.238	9.61
14	.083	3.35	3	$\frac{1}{4}+=.259$	10.47
12	.109	4.40	2	.284	11.48
11	$\frac{1}{8}-=.120$	4.85	1	$\frac{5}{16}-=.300$	12.13
10	.134	5.41	0	.340	13.74
8	.165	6.66	00	$\frac{3}{8}+=.380$	15.36
7	$\frac{3}{16}-=.180$	7.27			

weigh each plate used, as thereby any essential difference in thickness could be detected. Iron plates which have been subjected to the action of salt water are undesirable.

The Spring Valley Water Company, of San Francisco, California, strain their pipes from 11,400 to 13,000 lbs. per sectional inch.

The Virginia City and Gold Hill Water Company, of Nevada, has an inverted siphon (of inferior English iron) with a maximum pressure of 1,720 feet head, equal to 746 lbs. per square inch, No. 0 iron, with ⅝-inch rivets, being used at the lowest point of depression and subjected to a tensile strain of 13,310 lbs. The No. 9 iron is strained fully 15,000 lbs., and the No. 7 over 14,000 lbs., per sectional inch.

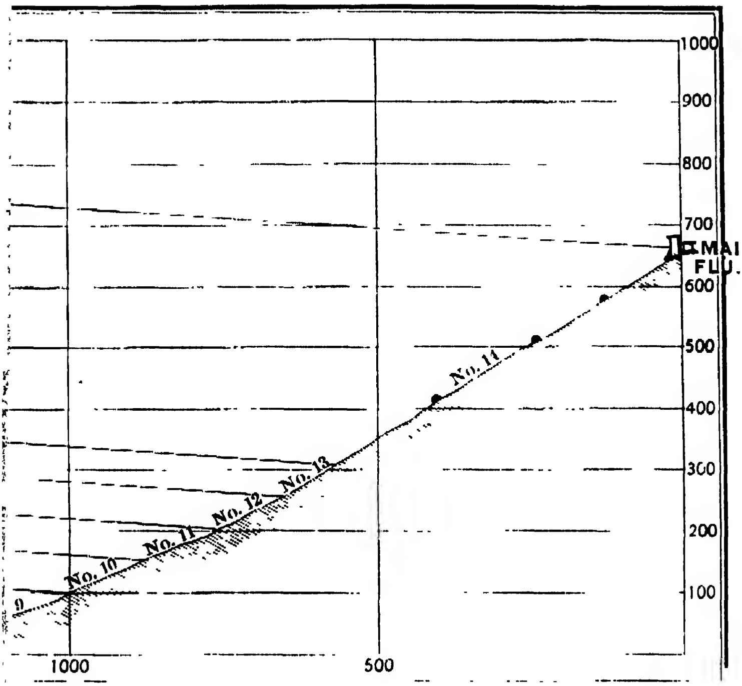
The Texas Creek pipe, four miles below the Bowman Dam, Nevada County, California, is an inverted siphon 4,438.7 feet long, 17 inches in diameter, made of riveted plate iron. Its inlet is 303 feet above the outlet, and with a full head it will discharge about 1,260 miner's inches. It sustains a maximum pressure of 770 feet or 334 lbs. per square inch.*

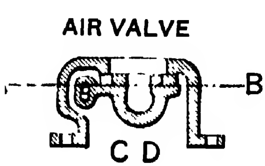
At Cherokee,† California, there is an inverted siphon of ordinary English plate, 30 inches in diameter, with a maximum pressure of 887 feet head.

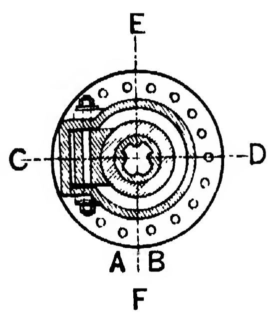
The maximum strains on the several sizes of iron used in practice are given in the following tables:

* See Official Report North Bloomfield Mining Co., 1878.

† For further description see p. 172.







Dots on profile, air-valves.

TABLE XVI

Area and Weight of Wrought-Iron Pipe.

Allowance for lap, 1½ and 2 inches.

Diameter.		Area.		Lap. Inches.	Sq. Feet in 1 Lineal Ft.	Weight of Iron per running foot of Pipe. Thickness in B. G. Nos. and inches.									
Inches.	Feet.	Inches.	Feet.			No. 14. 0.083 in.	No. 12. 0.109 in.	No. 11. 0.12 in.	No. 10. 0.134 in.	No. 8. 0.165 in.	No. 6. 0.203 in.	No. 4. 0.238 in.	No. 3. 0.259 in.	No. 1. 0.3 in.	No. 0. 0.34 in.
						Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
10	0.8333	78.54	0.545	1½	2.74	9.19	12.06	13.30	14.83	18.26	....	..	....	....	....
				2	2.78	9.32	12.24	13.50	15.06	18.53	22.52	26.77	29.14	33.76	38.24
11	0.916	95.03	0.659	1½	3.00	10.06	13.21	14.56	16.25	20.00	....	....	....	....	...
				2	3.04	10.21	13.40	14.77	16.47	20.28	24.96	29.29	31.88	36.93	41.84
12	1.000	113.10	0.785	1½	3.26	10.94	14.37	15.83	17.66	21.74	...	....	....	...	....
				2	3.31	11.08	14.55	16.04	17.89	22.02	27.12	31.81	34.62	40.11	45.44
15	1.25	176.71	1.227	1½	4.05	13.57	17.83	19.65	21.92	....	....	....	....	....	....
				2	4.09	13.71	18.01	19.85	22.14	27.26	32.56	39.37	42.85	49.65	56.24
16	1.333	201.06	1.397	1½	4.31	14.49	18.98	20.92	23.33	....	....	....	....	....	....
				2	4.35	14.58	19.16	21.12	23.55	28.99	35.70	41.88	45.59	52.81	59.82
18	1.50	254.47	1.767	1½	4.84	16.20	21.28	....	....	. .	....	....	....	....	....
				2	4.88	16.34	21.46	23.66	26.39	32.49	39.99	46.93	51.07	59.17	67.01
20	1.666	314.16	2.181	1½	5.36	17.95	23.58	....	....	....	...	....	....	....	.. .
				2	5.40	18.09	23.76	26.19	29.21	35.96	44.28	51.95	56.54	65.50	74.19
22	1.83	380.13	2.639	1½	5.88	19.71	25.88	....	....	....	....	....	....	....	....
				2	5.92	19.84	26.06	28.73	32.05	39.45	48.58	56.99	62.02	71.86	81.39
30	2.5	706.83	4.91	1½	7.98	....	....	....	....	....	....	....	....	....	....
				2	8.02	26.87	35.28	38.90	43.39	53.41	65.76	77.15	83.97	97.28	110.19

NOTE.—In practice the diameter of the pipe is not always the exact number given in the table, as it depends on the sheets used and the punching.

Riveting.—For ordinary pipe under light pressure a very common style is to have the seams single-riveted, the rivets (say ⅛ of an inch in diameter for an 11-inch pipe) being spaced 1 or 1¼ inch apart on the longitudinal seams, and sometimes as much as 3 inches apart on the circular seams. Pipe thus put together becomes water-tight in use through the particles which naturally float in the water, or can be made so by throwing in a few bags of sawdust or shovelfuls of dirt, and will remain tight even when subjected to a pressure as great as 200 lbs. per square inch.

For heavy pressures and more careful construction the circular seams have a single row of rivets 1 inch apart, while the longitudinal seams are double-riveted, with rivets spaced 1 inch apart in two rows about ½ inch from each other.

Cold-riveting is common. In very particular work only is hot-riveting resorted to.

TABLE XVII.

Sizes of Rivets used in General Practice.

No. 18 and 16 iron,	$\frac{3}{16}\times\frac{1}{2}$	No. 10.9 and 8 iron,	$\frac{3}{8}\times\frac{3}{4}$
" 14 "	$\frac{4}{16}\times\frac{1}{2}$	" 7 and 6 "	$\frac{1}{2}\times1\frac{1}{4}$
" 12 and 11 "	$\frac{5}{16}\times\frac{5}{8}$	" 3 "	$\frac{1}{2}\times1\frac{1}{2}$

TABLE XVIII.

Details of Riveting a 22-inch Pipe of the Spring Valley Water Co.

Thickness of the iron used.	Diameter of the rivets.	Length of the rivets.	Pitch of the circular seam.	Number of rivets in each circular seam.	Pitch of the rivets in the longitudinal seam of double row.	Width between the centres of the rivets in the double row.
No. 12	$\frac{3}{16}$ in.	⅜ in.	1 in.	69	1⅜ in.	⅝ in.
" 11	$\frac{5}{16}$ "	⅝ "	1 "	69	1⅜ "	⅝ "
" 9	⅜ "	$\frac{13}{16}$ "	$1\frac{3}{16}$ "	59	full $1\frac{7}{16}$ "	⅝ "
$\frac{3}{16}$ in.	½ "	1¼ "	$1\frac{7}{16}$ "	39	" $1\frac{11}{16}$ "	$1\frac{1}{10}$ "
¼ "	½ "	½ "	$1\frac{7}{16}$ "	39	" $1\frac{11}{16}$ "	$1\frac{1}{10}$ "

Joints.—The pipes in general use in the mines are 11, 15, 22, 30, and 40 inches in diameter, of riveted sheet iron Nos. 8, 10, 12, 14, or 16 (Birmingham gauge) made in sections of 30 to 36 inches, riveted into lengths of about 20 to 30 feet, which latter are very frequently put together in stove-pipe fashion, neither rivets, wire, nor other contrivance being necessary to hold the joints in place. This stove-pipe connection is sufficient in ordinary cases. When it will not suffice iron collars and lead joints are used.

The annexed sketch (Fig. 20) shows the style of joint

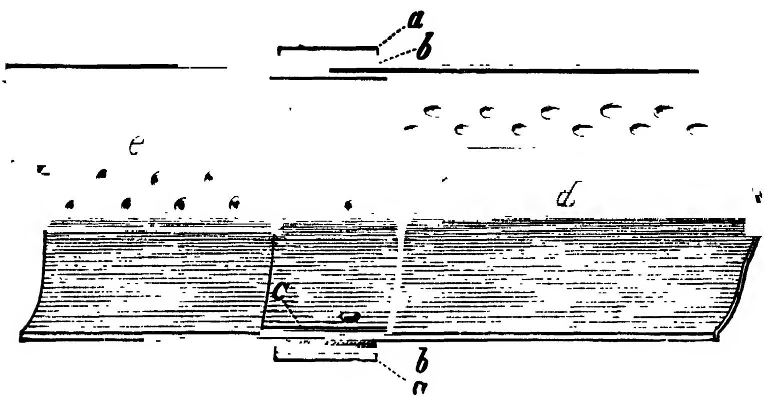


FIG. 20. LEAD JOINT.

originally used on the siphon of the Virginia City and Gold Hill Water Company.

The cut shows the joint which is made between every two lengths of pipe, or 26 feet 2 inches: *a* is a wrought-iron collar, 5 inches wide, $\frac{1}{16}$ of an inch thicker than the iron of the pipe, and with a play of $\frac{3}{8}$ of an inch between the inside of the collar and the outside of the pipe; *b* is the lead, which is run in and then calked tight from both sides; *c* is a nipple of No. 9 iron, 6 inches in width, riveted on one end of each pipe by means of six $\frac{3}{8}$-inch rivets.

Fig. 21 shows the method of tightening leaky joints: *a* shows the clamp and its application for forcing back the lead which has worked out through the expansion and

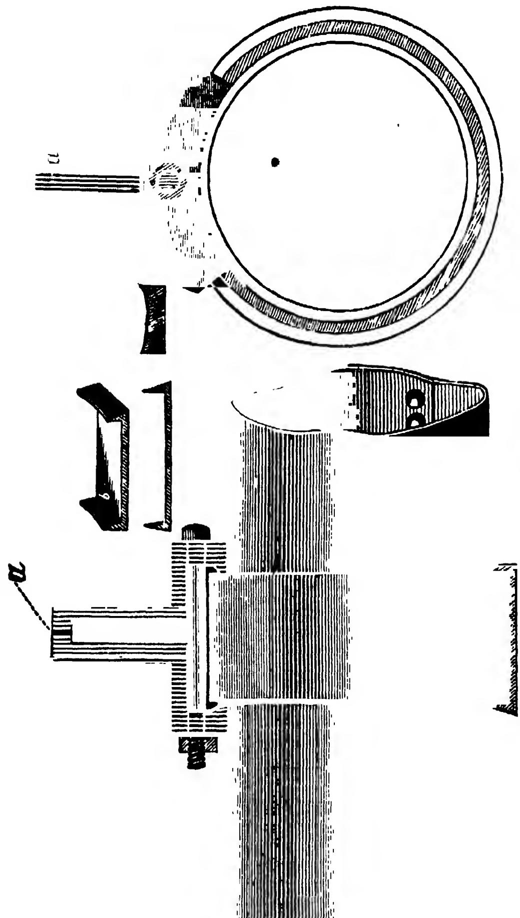


FIG. 21. METHOD OF TIGHTENING LEAKY JOINTS.

contraction of the pipe. This is shown both in perspective and in cross section. The clamp *b* is used to keep the lead in place after it has been forced back by the

clamp *a*. The two lower sketches of this clamp *b* show both the side view and the elevation.

Fig. 22 shows the elbow used in making short curves. *a a* are angle irons riveted on the pipe on the outside of the curves, and, by means of iron straps, connected

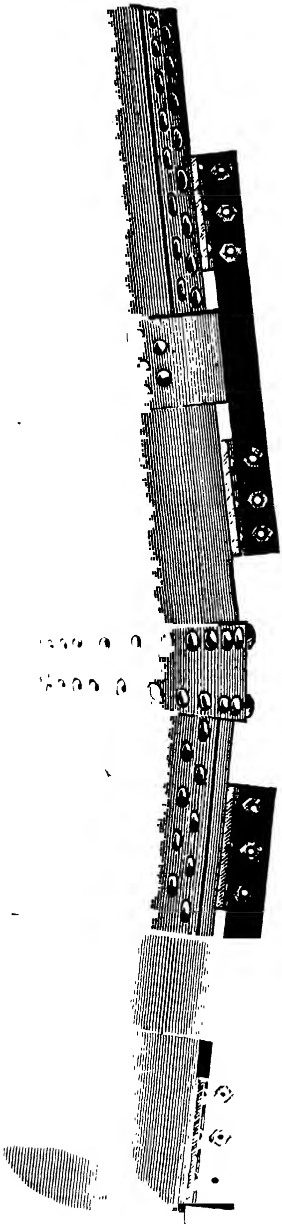


Fig. 23. Method of Strapping Elbows and Pipes

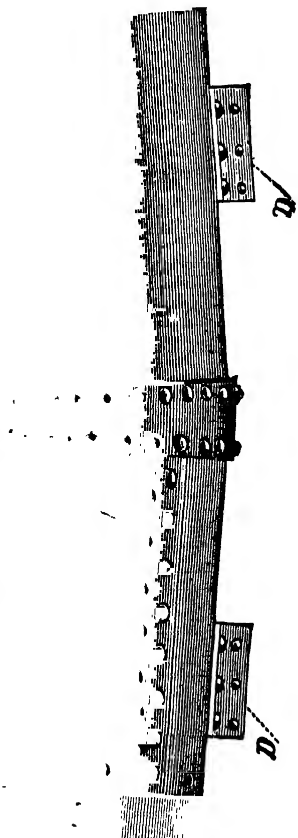


Fig. 22. Elbow for Short Curves.

with the corresponding angle irons on the next pipe, as denoted in Fig. 23, which shows the manner in which the pipes and elbows were strapped together whenever the curve was sufficiently short to require this precaution against an outward movement.

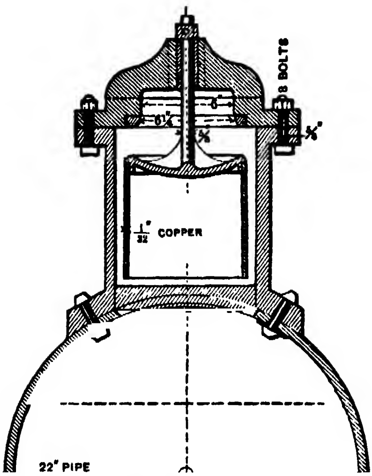


FIG. 24. AIR-VALVE FOR 22" WATER-PIPES.

Air - Valves, Blow-offs.—On a long line of pipe, or a siphon, "blow-offs" and air-valves are provided to allow the escape of the air from the pipe while filling, and especially to prevent a collapse of the pipe in case of a break. The valves in use are of varied make. A simple construction is a piece of leather loaded on the inside of the pipe, and arranged to cover an opening from 1 inch to 4 inches in diameter. A better class of valve is shown in Fig. 24.

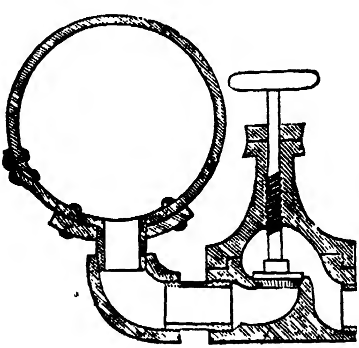


FIG. 25.

This sinks and opens when the water leaves it, and floats and shuts when the water rises to it.

The contrivances used on the Virginia City and Gold Hill Water Company's siphon are shown in Figs. 25 and 26.

Fig. 25 shows the blow-off used in every low place (also marked with a triangle in the profile, Fig. 27).

Fig. 26 shows the self-acting air or vacuum valve used at each high point on the line. When the water is on, the valve *a* is kept open and the valve *c* closed, while the self-acting valve *b* is shut by the pressure. If any air accumulates in the pipe it is blown off occasionally by opening the cock, *c*. Should a break occur in the main pipe-line at a point lower than the air-cock, and within its district, the valve *b* falls down and admits the air so as to prevent a vacuum. After a break on the main line is repaired and the water is let on again, the valve *b* being down or open, the air rushes out, the valve-stem being weighted, *d*, so as to close only when the water reaches it.

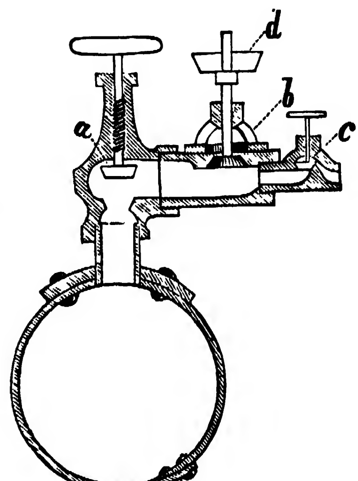


FIG. 26. SELF-ACTING AIR-VALVE.

Preservation against Rust and Accidents.—In order to protect the pipe it should (as far as possible) be laid in a trench and covered with earth to a depth of at least one foot for the ordinary conditions of hydraulic mining.

Wrought-iron pipes should be treated externally and internally with asphaltum or coal-tar, the life of a pipe being dependent to a very great extent upon this bituminous coating, which preserves the iron from rust and

the corroding action of water. Thin iron pipes well coated are still in good condition after fifteen years of service.

The following preparations have been found valuable in practice:

Crude asphaltum	28	per cent.
Coal-tar (free from oily substances)	72	" "
Or		
Refined asphaltum	16½	per cent.
Coal-tar (free from oily substances)	83½	" "

The (Santa Barbara) asphaltum, in small pieces, and the coal-tar are heated to about 400 degrees Fahr. and well stirred. The pipe is thoroughly dried and immersed in the mixture, where it remains until it acquires the same temperature as the mixture. When coated it is removed, placed on a trestle to drip and dry in the sun and air. For convenience of immersion wrought-iron troughs, some 30 feet long, 3 feet wide, and 2 feet deep, are used. No. 14 iron requires immersion for about 7 minutes, and No. 6 for 12 to 15 minutes.

Filling Pipes.—A pipe-line being finished, water must be admitted in such a way as to prevent the air from being sucked in, which will happen (and to a great extent) unless care is taken. The best plan is to put a gate in the pipe below the level where the water enters, and thus regulate the flow, maintaining a steady pressure and avoiding violent oscillations. The common plan of admitting the water through a pen-stock, which is kept filled so that the water is quiet, will answer if proper care is exercised.

STATISTICS OF PIPE-LINES.

La Grange Hydraulic Mining Company.—The following are the details of the cost and construction of 1,233½ feet of 22-inch wrought-iron pipe made at the works of the La Grange Hydraulic Mining Company, Stanislaus County, California.

The iron used was No. 16, U. S. wire gauge, or 0.05

inch thick. The pipe sections averaged 19 feet in length, containing each 8 sheets of iron 6 by 3 feet. The laps were 1½ inches at the joints and single-riveted, the rivets being driven 1¼ inches from centre to centre in $\frac{3}{16}$-inch-diameter holes. To each sheet of iron 77 rivets were used, 28 on the longitudinal and 49 on the circular seams. The heads of the rivets were ½ inch in diameter by $\frac{1}{16}$ inch thick, and the shanks ¼ inch in diameter by 0.44 inch long. The rivets weighed about ⅛ ounce each, or 128 to the pound.

COST OF ONE RUNNING FOOT OF PIPE.

Iron 57 6 sq. ft., or 11.82 lbs., at 4 cts.	$0 53
Rivets, 32, or 0.25 lb., at 13 cts.	0 03
Punching and rolling	0 12
Freight on iron and rivets, at 1 ct. per lb.	0 12
Labor contract per foot	0 25
Tarring	0 03
Total cost per running foot	$1 08

TABLE XIX.

North Bloomfield.—*A*. Cost of iron pipe at North Bloomfield, 22 inches diameter, No. 10 iron, double-riveted, per length of 17 feet 3 inches:

Six sheets iron 36″ × 72″, No. 10 = 540 lbs.,	at	4.38	cts.	$23 65
Freight, Sacramento to Bloomfield,	"	80	"	4 32
Rivets, $\frac{5}{16}$″ × ⅝″ = 12 lbs.,	"	10	"	1 20
Labor by contract, 17′ 3″,	"	25	" per ft.	4 31
Wear and tear of tools, 3 cts. per foot; tarring,	"	3	" "	1 03
Total cost of 17′ 3″ length				$34 51

or $2 per lineal foot.

B. Cost of iron pipe 22 inches diameter, No. 12 iron, double-riveted, per length of 17 feet 3 inches:

Six sheets No. 12 iron, 36″ × 72″ = 480 lbs.,	at	4.38	cts.	$21 02
Freight, Sacramento to North Bloomfield,	"	80	"	3 84
Rivets, $\frac{5}{16}$″ × ½″ = 10 lbs.,	"	10	"	1 00
Labor,	"	21	" per ft.	3 62
Wear and tear of tools, and tarring,	"	6	" "	1 03
Total cost of 17′ 3″ length				$30 51

or $1 77 per lineal foot.

The above pipe was double-riveted on the longitudinal seams, and single-riveted on the circular seams. The long-seam rivets were spaced 1¾ inches; the rows were 1 inch apart. The circular-seam rivets were spaced 1¾ inches apart. The sheets of iron were not cut, but punched so as to make a pipe full 22 inches diameter.

The No. 10 iron is used under 450 feet head, with nozzles as small as six inches in diameter. The No. 12 iron is used under 410 foot head, with nozzle as small as 7¼ inches in diameter.

The cost of an outfit of tools for large-pipe making (iron up to No. 10, B. G.) is as follows:

Rollers	$150 00
Stake	50 00
Punch	100 00
Hammer and tools	25 00
Fitting up, etc	75 00
Total	$400 00

Spring Valley Water Company, San Francisco. —The following figures,* given in tabular form, show the details of the construction of an 18-inch wrought-iron pipe, 5,800 feet long, made for the Spring Valley Water Company, which supplies the city of San Francisco. This pipe has a tensile strain of about 5,000 or 6,000 lbs. per sectional inch, and was made with this low coefficient in order to withstand the pulsations caused by a single-acting plunger pump making as high as 36 (four-foot) strokes per minute. These pulsations in practice vary from 5 to 9 lbs. per stroke when the air-vessel is properly charged, but through carelessness they may exceed 50 pounds.

* Details by Joseph Moore, Superintendent of the Risdon Iron-Works, San Francisco.

TABLE XX.

Details of Construction of Wrought-Iron Pipe for the Spring Valley Water Company, San Francisco, Cal.

Thickness of the bands.	Width of the bands.	Thickness of the sleeves.	Width of the sleeves.	Width of the sheets used in the pipes.	Thickness of the iron used in the pipes.	Diameter of rivets used.	Pitch of the circle seams in the outside courses.	Pitch of the circle seams in the inside courses.	Amount of two laps.	Space between double row.	Length to the joining holes in the outside courses.	Length to the joining holes in the inside courses.	Whole length of the outside courses.	Whole length of the inside courses.	Spaces in the circle seams.	Pitch of the double row.	Spaces in the double row.	Amount of the two outside spaces of the double row.	Amount of two laps for the double row.
In.	In.	No.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
5-16	4½	11	5½	42	¼	⅜	1.45229	1.4106233	2	1.10	56.63931	55.01431	59.739	58.114	39	1.7223	22	2.1094	2
¼	4⅝	11	5⅜	42	3-16	½	1.45229	1.4207515	2	1.10	56.63931	55.40931	59.739	58.509	39	1.7223	22	2.1094	2
¼	4⅜	11	5½	44	3-16	½	1.45229	1.4207515	2	1.10	56.63931	55.40931	59.739	58.509	39	1.7223	23	2.3871	2
					Nos.														
¼	4⅜	11	5½	42	9	⅜	1.197	1.7915	1.625	.625	57.456	56.5999	59.706	58.8492	48	1.468	26	2.207	1.625
¼	4½	9	5½	40	11	5-16	.9934692	.9816157517	1.5	.625	57.6212136	56.9337136	59.746	59.0575	58	1.468	25	2.05	1.25
¼	4½	9	5½	42	11	5-16	.9934692	.9816157517	1.5	.625	57.6212136	56.9337136	59.746	59.0575	58	1.468	26	2.332	1.5
¼	4½	9	5⅜	40	12	5-16	.9934692	.9837709	1.25	.625	57.6212136	57.0587136	59.496	58.9333	58	1.468	25	2.05	1.25
¼	4½	9	5⅜	38	12	5-16	.9934692	.9837709	1.25	.625	57.6212136	57.0587136	59.496	58.9333	58	1.468	24	1.518	1.25

Virginia City Water-Works.—The Virginia and Gold Hill Water Company have an inverted siphon across the Washoe Valley, Nevada, 7 miles long, 11½ inches in diameter, of riveted wrought iron. The total weight of the siphon is about 700 tons. The pipes were hot-riveted, with a single row on the circular and a double row on the longitudinal seams, a million rivets being used. The separate lengths were united by lead joints, previously described (see p. 163). For these 35 tons of lead were required. The pipe was constructed in 1872 of inferior English iron, but is still (1883) in good condition. The No. 9 iron is strained fully 15,000 lbs., and the No. 7 over 14,000 lbs., per sectional inch. The pipe is said to have been tested to a pressure of 1,400 lbs. per square inch.

The annexed sketch (Fig. 27) shows the profile. The numbers along the line give the thickness of iron, B. G., used under the various pressures which are indicated in the perpendicular columns of figures from 100 to 1,700 (feet), at the points where the parallel lines strike the profile. The triangles below the line denote the locations of the blow-offs, and 0, above the line, represents the air-valves. These have been previously described (see pp. 166, 167).

Spring Valley and Cherokee Hydraulic Mining Company.—At Cherokee, Butte County, California, the Spring Valley and Cherokee H. M. Company has an inverted siphon of wrought iron, 30 inches in diameter, which discharges 53 cubic feet of water per second. This was the first large construction of the kind on the coast. It has been in continuous use for 12 years, and is still in good condition. The material was ordinary English plate. The greatest pressure is 887 feet.

The sketch * (taken from the original survey) shows the profile and the different sizes of iron used. The maxi-

* The *Mining and Scientific Press* of January 7, 1871, contains a detailed account of the construction of this pipe and a diagram of the line.

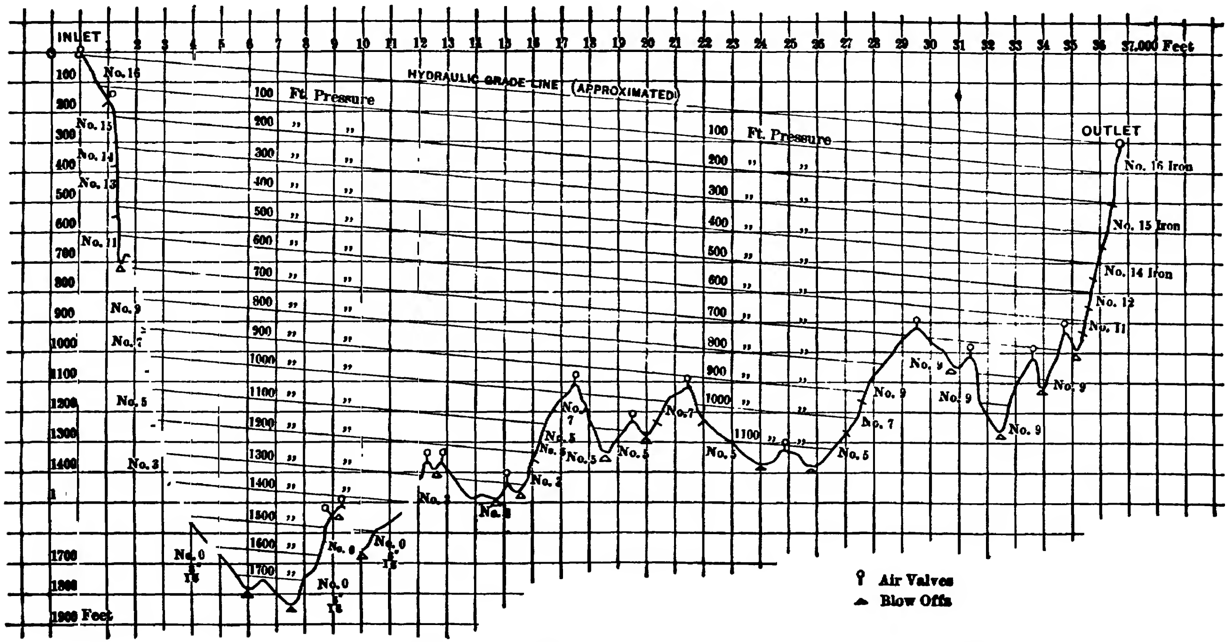


FIG. 27. PROFILE OF IRON PIPE FOR THE VIRGINIA AND GOLD HILL WATER-WORKS.

Average Diameter of Pipe, 11½ inches. Circular seams single-riveted, longitudinal seams double-riveted. Capacity, about 2,000,000 gallon. in 24 hours. Pressure, 1,720 feet, or 746 pounds per square inch. Length of pipe, about 37,100 feet. Laid in 1872 by Hermann Schussler, Civil Engineer. Total fall, 300 feet.

mum strains on each size are given in the following table:

TABLE XXI.

Details of Spring Valley and Cherokee Pipe.

Size of Iron. Birmingham Gauge.	Greatest Pressure. Feet head.	Greatest Pressure. Pounds per square inch.	Maximum tensile strain, in pounds per sectional inch.
No. 14	170	74	13,374
" 12	288	125	17,202
" 11	293	127	15,875
" 10	355	154	17,240
" 7	435	188	15,080
" 3	594	257	15,420
" 1	842	365	17,549
" 00	887	384	15,360

Flow of Water through Pipes.—A series of experiments on the flow of water through circular pipes was made by Hamilton Smith, Jr., at the works of the North Bloomfield Mining Company and at New Almaden, in Santa Clara County, California. The details of these experiments were communicated by him to the American Society of Civil Engineers.

The following table (XXII.), compiled by Mr. Smith, shows the results of 88 experiments as to the discharge of water through circular pipes "varying from 4 feet to ½ inch in diameter," and with velocities varying from 20 feet to ⅙ of a foot per second. The standard of measure used was that of the United States Coast Survey. The temperature of the water in Nos. 35 to 87 was about 65° Fahr.; in the other experiments, from 50° to 55° Fahr.

One-inch gas-pipe, with funnel; pipe had been several years in use.

Five-eighths-inch new gas-pipe, no funnel.

One-inch glass pipe, with funnel.

Three-fourths-inch glass pipe, no funnel.

One-half-inch glass pipe, no funnel.

Wooden one-and-a-quarter-inch pipe, no funnel.

Pipe carefully tarred and comparatively new.

The experiments are all reduced to the formula:

$$v = m\left(\frac{dh'}{l}\right)^{\frac{1}{2}}$$

where v = velocity in English feet per second.
d = mean diameter.
l = length.
h' = effective head.
m = variable coefficients.

"The effective head h' was derived from the total head h as follows, c being coefficient of contraction at entrance:" *

$$h - h' = \frac{v^2}{2gc^2}$$

THE PRESSURE BOX.

The pressure box is situated at the end of the ditch in a commanding position above the claim, and from it the water is delivered into the supply pipe. The box derives its name from the fact that the head or pressure is measured from this point. Connected with or forming a part of the pressure box is the sand box, which is sunk below the level of the flume or ditch, and arranged to catch the gravel or sand carried along by the current. It is emptied by a side gate as circumstances may require.

The pressure box is a large wooden receptacle, generally constructed of 1½-inch planks, and securely held together with timbers. It is sufficiently large and deep to keep the head of the pipe, which enters it, under water with a steady pressure.

A grating of bars is arranged to catch all floating material, such as sticks and leaves. The water should be quiet and sufficiently deep to prevent any air from being carried into the pipe. For this purpose the box is divided into compartments, one of which receives the water and

* See "Trans. of the Am. Society of Civil Engineers," vol. xii. No. 204, pp. 120–123.

quietly discharges it into the second through lateral openings. There should be no perceptible difference between the water-supply and the discharge, or, if any, the former should be in excess, and the surplus should be regulated and discharged by a waste-gate placed near the end of the flume. Some pressure boxes are arranged for two pipes.

La Grange Pressure Box.—The following is a description of a pressure box at the La Grange Mine, Stanislaus County:

Some 350 feet to the rear of the pressure box there is a sand box in the ditch connecting with the waste-way. This sand box is 2 feet deep (below the bottom of the ditch), 4 feet wide, and 4 feet 3 inches long, and communicates with the waste-way by means of a gate which slides clear to the bottom of the box. At the pressure box the four end posts and the two caps belonging to them are made of 6″×8″ lumber. The six intermediate posts, three on a side, are of 6″×6″ material, and their caps are of the same dimensions. All the sills, and the two longitudinal stringers on which they rest, are of 6″×8″ "stuff." Up to high-water mark the box has a double lining made of two 1½-inch planks battened at the joints with strips ½ inch by 4 inches. A 22-inch pipe takes the water. Nine feet from the box there is a 5-inch diameter stand pipe which extends 2 feet above the top of the pressure box.

In large claims the pressure box ranges from 10 to 20 feet in length with a single pipe, and, where two pipes are used, from 12 to 30 feet. Larger boxes are also built where the pressure, sand, and measuring boxes are combined in one.

The pressure box at the Bloomfield Mine is 18 feet long and 6 feet wide, so arranged that the sand falls under a wooden diaphragm into a large chamber provided with a gate.

THE SUPPLY OR FEED PIPES.

The water is conveyed in iron feed pipes from the pressure box to the claim, and by means of iron gates on the lower end of the feed pipes it is distributed to the discharge pipes. The supply pipe is funnel-shaped where it connects with the pressure box, and from there on it is usually of uniform diameter as far as the gate or discharge nozzle.

Where 22 to 30-inch pipes are used it is not advisable to use lighter iron than No. 14, B. G., even under extremely low heads, as lighter pipe of that size will not bear handling.

The main supply pipe should descend in the most convenient and direct line into the diggings, avoiding, so far as practicable, angles, rises, and depressions. Air-valves should be arranged at proper distances to allow the escape of air when filling the pipe, and also to prevent any collapse. Where the pipe passes over steep banks into the claim it is carried on a trestle and braced, care being taken to prevent any movement of the column. When necessary the pipe is secured with frame-work and weighted with stones. At all angles the pipe is braced and weighted.

In filling the supply pipe the water should be turned on gradually, all sudden straining of the column being thus avoided. Leakage in the slip joints can be readily stopped with a few bags of sawdust or by wedging them with thin pieces of soft pine. Large leaks have to be closed by iron grip-bands drawn together by means of screws or wedges.

The lower end of the supply pipe was formerly fitted into a distributing box of cast iron, from which one or more branch pipes were taken by means of gates. These are now abandoned owing to their great cost and liability to burst.

The present practice is to fork the main pipe wherever

an attachment is required, cast-iron gates being placed on each branch. The annexed sketch (Fig. 32) shows the form of these gates used in the mines, and also as a discharge gate for reservoirs.

Where several branch pipes are supplied from the same main pipe they are usually of smaller diameter.

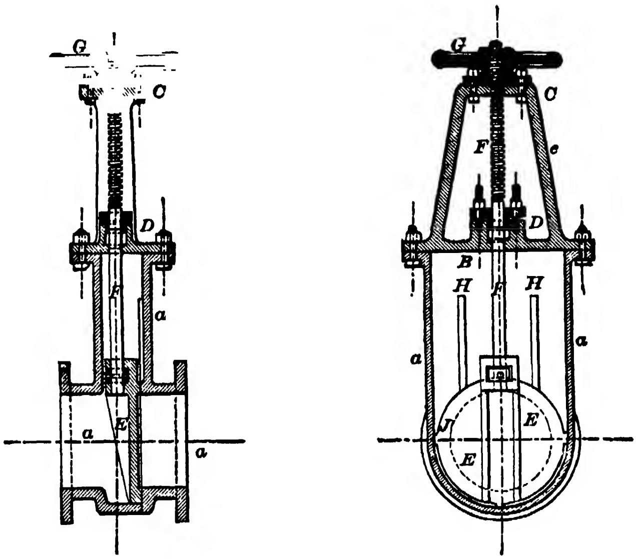


FIG. 32. DISTRIBUTING GATE.

Their use arises from the greater convenience of moving the smaller pipes. They are generally 11 and 15 inches in diameter. It is recommended, however, in order to prevent a loss of head, to continue the branch pipes of the same size as the feed pipe, and to regulate the discharge by the size of the nozzles. At the Southern Cross and Polar Star Mines the supply pipes at the pressure box are 40 inches and 48 inches (respectively) in diameter, tapering for 500 feet to 22 inches, which size they retain for 2,800 feet, then branching into two pipes each of 15 inches. At the Malakoff the pipe at the head is 27 inches, narrow-

ing to 22 inches and 15 inches for the branches. At this mine nozzles of 6 inches to 9 inches diameter are used under a head of 450 feet. At the American Mine the pipes are 34, 22, and 15 inches. At the Bonanza Mine all the pipes are 16 inches. At the Milton Company's Manzanita Mine the pipe is 22 inches from the pressure box to the nozzles. This pipe is 4,000 feet long, with a head of 430 feet.

THE DISCHARGE PIPE OR NOZZLE.

Goose Neck.—The first improvement in discharge pipes was a flexible iron joint formed by two elbows, one working over the other, with a coupling joint between them. These elbows were called *Goose Necks*.

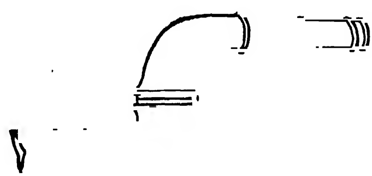


FIG. 33.

Their construction was very defective. The pressure of the water caused the joint to move hard, and when the pipe was turned horizontally it was apt to "buck," or fly around in a contrary direction. The same thing occurred in elevating and depressing the pipe.

Globe Monitor.—The Goose Neck was succeeded by the Craig Globe Monitor, a simple ball-and-socket joint, which was difficult to work, often requiring several men to manipulate it.

A subsequent invention of Mr. Craig was the interior tripod and belt. "This was a tripod with a centre having a hole to take a bolt with a knob on the end; the other end passed out through the top of the elbow and had a nut with a lever. By tightening the nut it threw

the strain on the bolt and reduced the friction on the joint proper." These machines were hard to manage and soon became leaky at the joint.

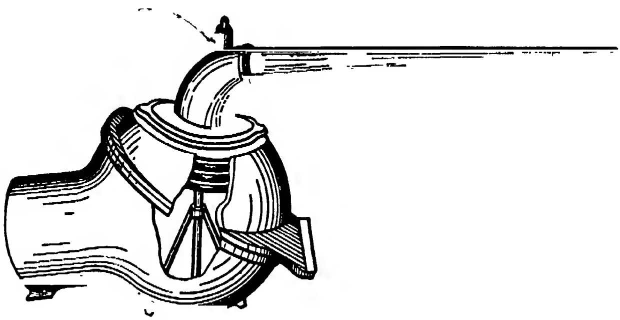


FIG. 34. CRAIG'S GLOBE MONITOR.

Hydraulic Chief.—The invention of Mr. Craig was succeeded by the "Hydraulic Chief," sometimes known as the "Knuckle-joint and Nozzle," invented by Mr. F. H. Fisher. The main features consist of two elbows placed

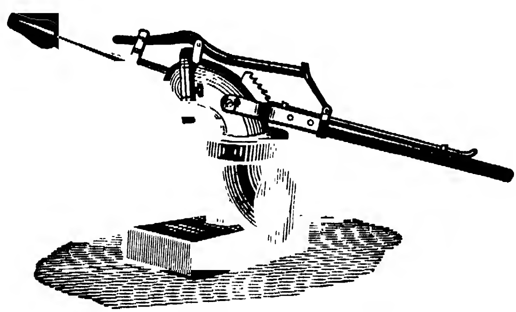


FIG. 35. THE HYDRAULIC CHIEF.

in reversed position when in right line, connected by a ring in which there are anti-friction rolls. The ring is bolted to a flange on the elbow, but gives the upper elbow a free horizontal movement, while the vertical motion is obtained through the knuckle-joint, which is placed

in the outlet on the top elbow. This joint is simply a concave surface fitted to a convex one, the former having an opening for the pipe to pass through.

The interior of the machine is unobstructed by any bolts or fastenings, and the man at the pipe can operate it by means of the lever without personal danger. Vanes, or rifles, are inserted in the discharge pipe to prevent the rotary movement of the water caused by the elbows, and to force it to issue in a straight line, concentrated and in a solid form. These machines soon become leaky and are expensive to keep in order.

Dictator.—In 1870 the Hoskins Dictator was patented. This was a one-jointed machine, having an elastic packing in the joint instead of two metallic faces. The joint worked up and down on the pivots, and in rotating it the wheels ran around up against the flange. This machine, though simple, is but little used.

Little Giant.—Mr. Hoskins subsequently invented

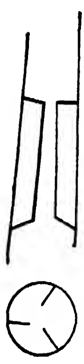


FIG. 37. THE LITTLE GIANT RIFLE.

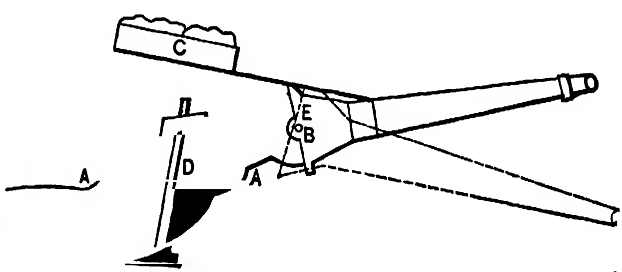


FIG. 36. THE LITTLE GIANT.

the "Little Giant," a two-jointed machine, which, on account of its simplicity and durability, rapidly superseded all others. It is portable and easily handled, having a knuckle-joint and lateral movement. The Giants have rifles, and nozzles from 4 to 9 inches in diameter, 5½ to 7-inch nozzles being most generally used.

In setting Giants they must be firmly bolted to a heavy piece of timber, and this timber securely braced against the solid gravel or rock. The machine and adjacent length of pipe must also be weighted to the ground. The bearings should be lubricated. Tallow or axle-grease is preferable to oil for this purpose.

Hydraulic Giant.—The Hydraulic Giant is a modification of the Little Giant. The several sizes, as constructed by Joshua Hendy, are as follows:

No.	Inlet, inches.	Outlet, inches.	Inside Diam. Nozzle Butt.	Weight, lbs.
1	7	5½	4 in.	245
2	9	7	5 "	450
3	11	7½	5 or 6 "	665
4	11	9½	7 "	750
5	15	9½	8 "	875
6	15	11	9 "	1,050

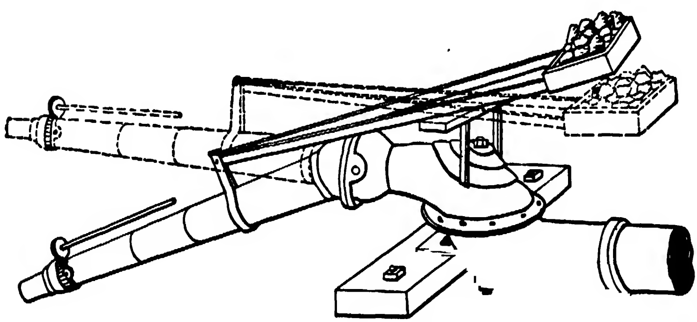


FIG. 38. THE HYDRAULIC GIANT.

Monitor.—Fig. 39 represents a Monitor Hydraulic Machine with a "deflecting nozzle," the invention of Mr. Henry C. Perkins.

Deflector.—By means of the "deflecting nozzle" the Giant can be turned to any point and the stream directed with the greatest facility.

A, Cast-iron nozzle.

B, Deflecting nozzle of wrought iron, attached to *A* by a joint similar to a compass gimbal.

C, Lever to govern the movement of *B*.

D, Rest for lever *B*.

The operation is as follows: When the lever, *C*, is in the rest, *D*, the deflecting nozzle, *B*, being of a larger diameter than nozzle, *A*, allows the stream of water from nozzle, *A*, to pass through without obstruction. To move the pipe the lever is taken from the rest and thrust in the direction in which it is desired to throw the stream. Any movement of the lever, *C*, either to the right or left, or up or

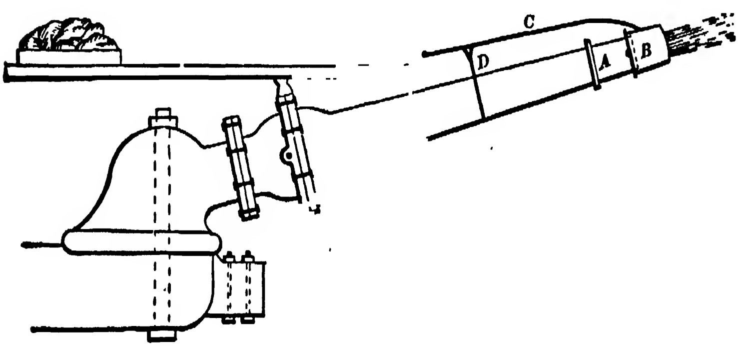


FIG. 39. MONITOR HYDRAULIC MACHINE.

down, throws the end of the nozzle, *B*, into the stream of water. The force of the water striking *B* changes the course of the discharge, the entire machine moving in accordance with each change of the deflector.

Hoskins' deflecting nozzle is of cast iron, of the same size as the main nozzle, to which it is attached by a packed universal joint. This deflector is operated by a lever in a manner similar to that already described. It has the disadvantage of causing a constant interference with the stream of water, and is somewhat dangerous to use.

CHAPTER XII.

VARIOUS MECHANICAL APPLIANCES.

Derricks.—Strong derricks are used in hydraulic mines to facilitate the removal of large boulders and rocks, which are of frequent occurrence. The present style of bed-rock derrick has a mast 100 feet high, and a boom 92 feet long, which is set in a cast-iron box placed on sills. The mast is held in position by six guys of galvanized iron wire rope one inch in diameter. A whip block, with three-quarter inch diameter steel rope, is used for the hoisting tackle. A twelve-feet diameter Hurdy-gurdy wheel is attached, and, using 30 inches of water under 275 feet head, it lifts stones weighing eleven tons. The guys are held by double capstans.

This derrick can be readily moved 100 feet in ten hours without being taken down.

Hurdy-gurdy Wheels.—Derricks and electric-light machines necessitate the employment of a motor, particularly one driven by water, and capable of utilizing high heads. Hence the use of water-wheels of the class known as "Impact* Wheels," locally called "Hurdy-gurdys."

These are wheels moved by a stream or jet of water issuing under pressure from a conical nozzle and striking open buckets on the circumference of the wheel. The buckets, originally flat, have been modified in shape, and thereby the efficiency of the wheel greatly increased.

Experiments at North Bloomfield.—The first

* See comment on the use of this term, p. 194.

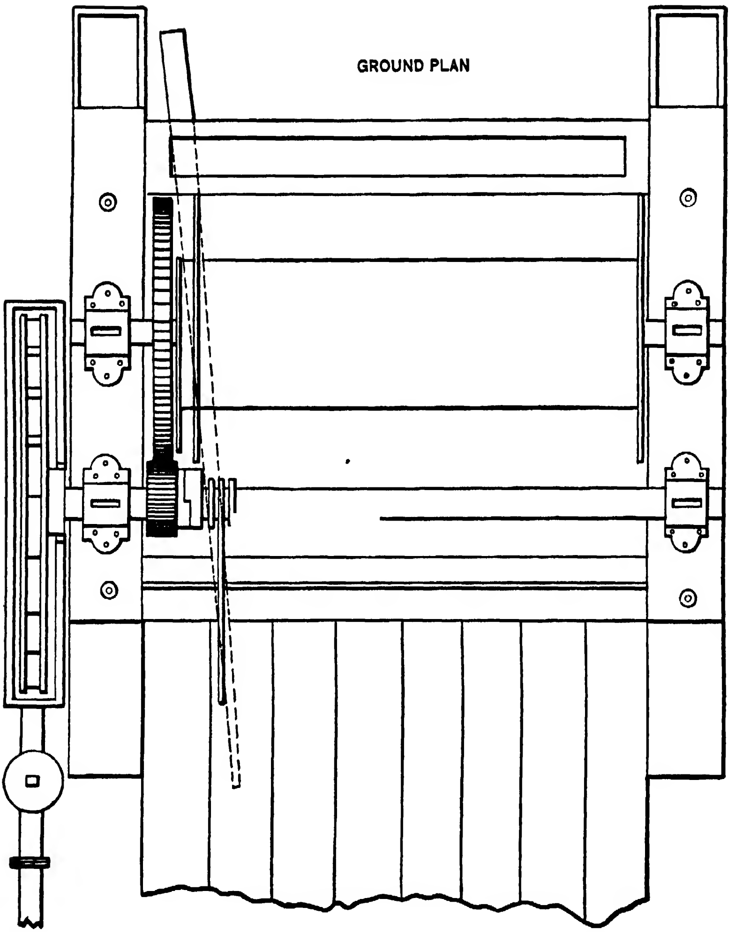


FIG. 40. HURDY-GURDY WHEEL AND DERRICK-HOIST.

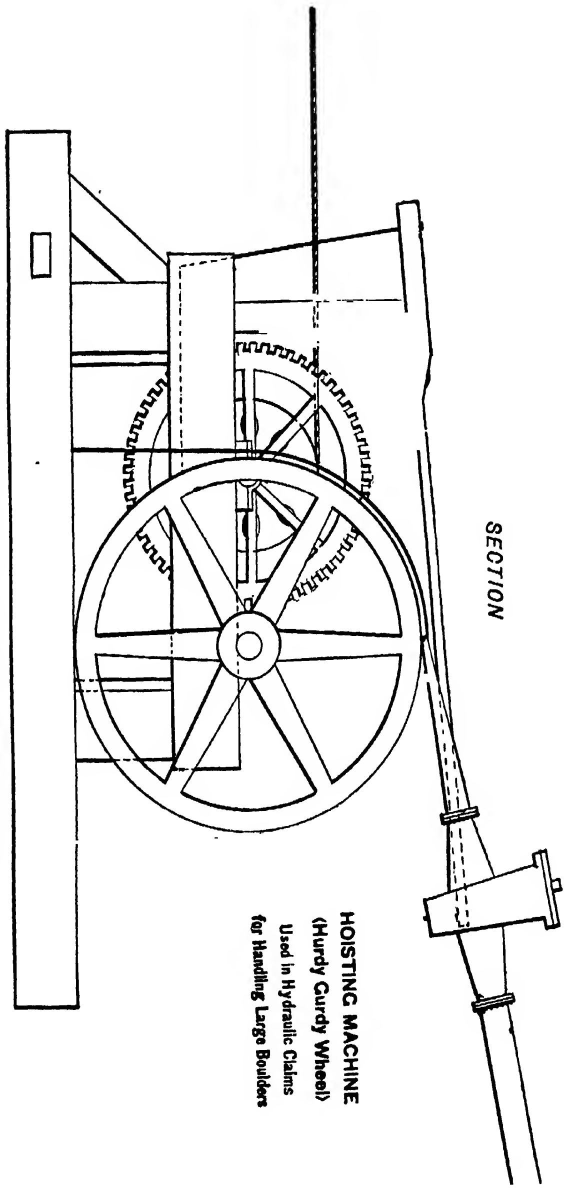


FIG. 41. HURDY-GURDY WHEEL AND DERRICK-HOIST.

noteworthy experiments recorded were made about ten years ago by Hamilton Smith, Jr., at North Bloomfield. The wheel was of the ordinary pattern with flat buckets, 18 feet in diameter on the outside and 17 feet 4 inches in diameter to inner line of buckets (17 feet

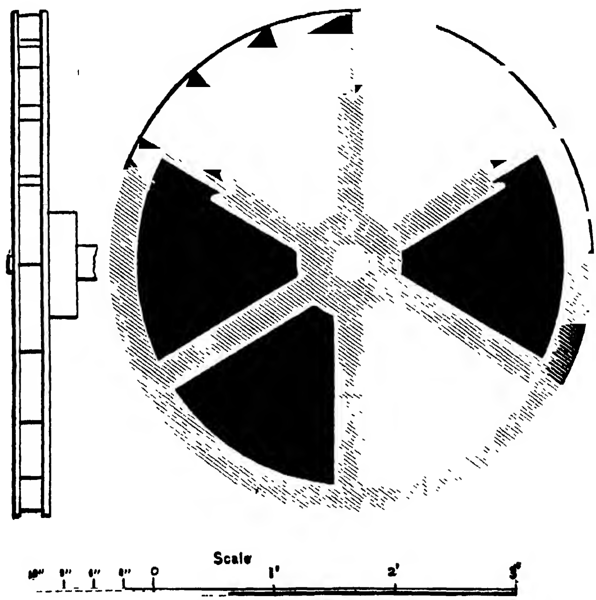


FIG. 42. HURDY-GURDY WHEEL.

8 inches in diameter at centre line of buckets). The buckets were 4 inches deep, with flanges on each side. The work done was measured by a Prony dynamometer.

The following table shows the result obtained. The head given shows the real head in feet at the point of the discharge.

TABLE XXIII.

Description of nozzle.	Diameter of nozzle in feet.	Head, in feet, at nozzle.	Discharge of water per second in cubic feet.	Velocity of water due to gravity.	Actual velocity of water at smallest diameter of nozzle.	Speed of wheel at centre of buckets when running light.	Highest horse-power developed.	Ratio of work done to theoretical power of water.	Speed of wheel at centre of buckets when giving most work.	Number of nozzles. See sketches.
Nozzle tapered.........	.0531	322.3	.323	144.0	145.8	82.8	3.8	.318	48.8	1
Ring....	.0597	316.3	.240	142.6	85.7	76.4	2.7	.312	44.8	2
Nozzle tapered.........	.0850	312.1	.759	141.7	133.7	93.6	11.7	.437	57.1	3
Ring.......	.0847	{ 312.6	.511	141.8	90.7	....	7.5	.414	54.7	4
		{ 312.2	.509	141.7	90.3	90.4	...	....	....	4
Nozzle.....	.0850	314.4	.774	142.2	136.4	....	11.8	.427	57.3	3
Nozzle tapered, uncut..	.0868	316.1	.813	142.6	137.4	....	11.3	.387	59.8	5A
Nozzle.................	.1017	{ 317.9	1.111	143.0	136.8	....	15.9	.396	66.1	7
		{ 315.6	1.110	142.5	136.7	95.2	....	....	....	7
Nozzle cut off..........	.0868	{ 332.6	.831	146.2	140.4	....	13.0	.413	58.2	5B
		{ 335.9	.833	147.0	140.8	98.5	....	....	....	5B

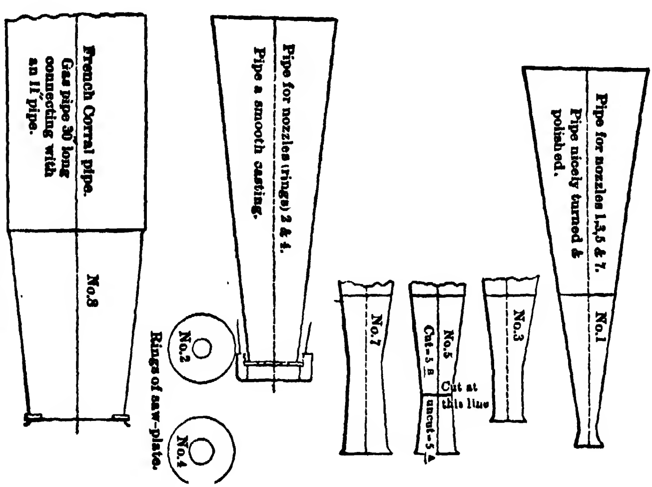


FIG. 43. NOZZLES.

Experiments at the Empire Mill.—An experiment at the Empire Mill, French Corral, was made under the following circumstances, giving the annexed results: Ten stamps, weight of each 693¼ pounds. Drop, 0.768 feet. Speed of stamps, 62.2 drops per minute. Work done by 91.68 cubic feet of water per minute head, 130.1 feet. Size of wheel, 13⅛ feet outer diameter. Diameter of wheel, 12.58 feet to centres of buckets. Size of buckets, 4 inches wide and 6 inches deep, set 10 inches apart. Water conducted to wheel through an 11-inch pipe 866 feet long. The wheel was direct on the cam shaft; single cams used. The mill crushed 60 tons of gravel in 24 hours; one-quarter-inch screens were used.

Description of nozzle	Ring.
Diameter of nozzle in feet	.182
Head, in feet, at nozzle	130.1
Discharge of water per second in cubic feet	1.528
Velocity of water due to gravity	91.4
Actual velocity of water at small diameter of nozzle	58.5
Speed of wheel at centre of buckets when running light.	......
Highest horse-power developed	10.0
Ratio of work done to theoretical power of water	.445
Speed of wheel at centre of buckets when giving most work	41.0
Number of nozzle (see sketch)	8.

The head at French Corral was the height of the water in pen-stock above the nozzle, no allowance being made (as in the North Bloomfield experiments) for the loss of head by friction in pipes and by leakage.*

Curved Buckets.—Recent patterns of wheels with curved buckets have given an efficiency very much in excess of that described above.

Tests at the Idaho Mine.—A series of comparative tests was made in the spring of 1883 at the Idaho Mine,

* All the data given on pages 189 and 190 concerning Hurdy-gurdy wheels were communicated by the author to the American Institute of Mining Engineers in a paper read at the Wilkesbarre meeting, May, 1877. See vol. vi. "Trans. Amer. Inst. Mining Engineers."

Grass Valley, with the Fredenburr, Pelton, Knight, and Taylor wheels, the results of which are given below. The tests were made in public, all owners of wheels having a right to compete. Prony's Friction Dynamometer was used, the brake acting on wheels 6 feet in diameter. The point of contact with the scale beam (57.3 inches) described a circumference of 30 feet. The supply main was 6,900 feet long, 22 inches in diameter, with a head of 386½ feet at nozzle. A pressure gauge placed a short distance back from the discharge nozzle (1.89 inches (?) in diameter) is said to have registered standing 165 pounds, and running 162 pounds. The water from the wheel was discharged into a flume 36 feet long, 36.5 inches wide, and 24 inches deep. There were three check-boards placed in the flume below where the water entered. The hook gauge, arranged on one side of the flume, was set 24 inches back from the weir. The water passed freely around the hook and was very quiet in the flume. A weir, 12 inches deep and 36½ inches wide, made of ⅛-inch iron, over which the water flowed without contractions, was placed at the end of the flume. Francis' formula for the discharge of water over weirs was adopted as the basis of the calculations.

The following are the official returns:

FREDENBURR WHEEL.

Weight on brakes, lbs.	Revolutions.	Horse-power.	Head of water over weir, inches.	Cubic ft. of water per minute.
444⅛	196	79.2	4.975	163.211
358½	260	84.2	"	"
361½	246	80.8	"	"
338½	276	84.4	"	"
298	281	76.1	"	"
358	259	84.3	"	"

Other tests were made of this wheel, resulting in an average of 82.925-1000 horse-power [?], utilizing 69.6-10 per cent. of the force and impact of the water.

PELTON WHEEL—FIRST TEST.

Weight on brakes, lbs.	Revolutions.	Horse-power.	Head of water over weir, inches.	Cubic ft. of water per minute.
465	254½	107.58	4.975	163.211
465	255	107.79	"	"
460	256	107.05	"	"
460	256½	107.26	"	"
SECOND TEST.				
465	256½	108.43	4.950	162.98
470	249	108.39	"	"
460	257½	107.68	"	"
465	254	107.37	"	"
LOWER NOZZLE.				
460	257	107.47	4.950	162.98
465	254½	107 58	"	"
STILL LOWER.				
465	253	106.95	4.950	162.98
HIGH NOZZLE.				
465	256	108.21	4.950	162.98
465	249	105.26	"	"

Average horse-power, 107.49-100, or 90.2-10 per cent.

KNIGHT WHEEL—FIRST TEST.

Weight on brakes, lbs.	Revolutions.	Horse-power.	Head of water over weir, inches.	Cubic ft. of water per minute.
430	217	84.8	....	152.60
400	233	84.36	....	"
400	236	85.8	...	"

The cubic inches of water in this test were reckoned on the amount of miner's inches used, allowing 1.40 cubic feet per minute for 1 miner's inch —this shows 77.18 per cent. of the power of the water.

SECOND TEST.

460	241	100.78	5.325	180.72
475	204	88.09	5.100	160.35

Average per cent. of first test, 76.5-10. Average per cent. of second test, 71.2-10. These were the only tests made of this wheel, the nozzle breaking and there being no other on hand.

TAYLOR WHEEL.

Weight on brakes, lbs.	Revolutions.	Horse-power.	Head of water over weir, inches.	Cubic ft. of water per minute.
400	184	66.91	4.975	163.211
312⅛	254	72.16	"	"

Average per cent. of first test, 55.1-10. Average per cent. of second test, 60.5-10.

The accuracy of the weir measurements may be considered doubtful. From the data obtained it did not appear that the increased discharge due to velocity of approach had been taken into account. To check this es-

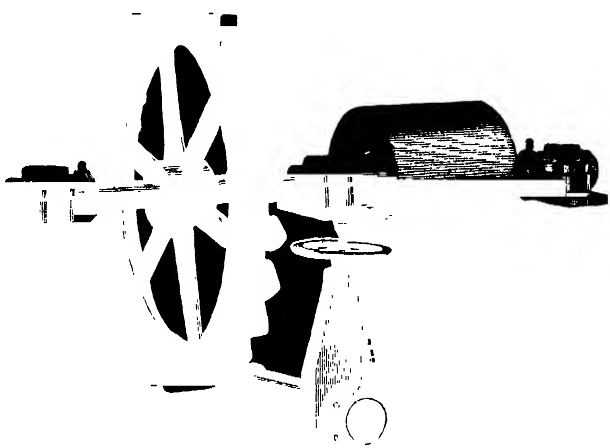


FIG. 44. THE PELTON WHEEL.

timate of flow the diameter of the nozzle above given could not be used, as it was not accurately measured and the coefficient of efflux had not been established. However, sufficient is known to justify the assumption that the efficiency of the Pelton wheel is at least 86 per cent.

Tests at the University of California.—The latest and most accurate data are derived from a monograph by Ross E. Browne, of the University of California; these, with the permission of the author, are here given entire.

Hurdy-gurdy wheels are commonly called "Impact

wheels," though such a name is misleading, and entirely loses its significance when the bucket is given its best form. When a jet of water strikes a stationary bucket shaped as shown in Fig. 45 or in Fig. 46, as soon as the motion has become permanent the wedge-shaped portion of the water shaded with horizontal lines becomes practically stationary. We have actual impact only for a minute interval of time—*i.e.*, while the wedge is forming. After this the water is simply deflected from its course, and the bucket becomes almost instantaneously a pressure bucket.

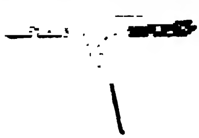


FIG. 45.

FIG. 46.

When such a bucket is used for a wheel it is plain that this shaded portion of the water is "carried" and must subsequently escape with nearly the full velocity of the bucket. Its useful effect is therefore very small as compared with that of the water actually deflected. No advantage comes, then, from impact; on the contrary, serious losses are due to it.

The originally flat bucket (see Fig. 45) has been materially improved:

1st. By giving it curvature (see Fig. 46).

2d. By filling in the wedge and making it a part of the bucket. This second improvement brings us to the "Pelton wheel" (see Fig. 53), which is by no means an "impact" but distinctly a "pressure" wheel. By filling in the wedge impact is avoided. The same thing in principle could be accomplished with the simply curved bucket by having the jet strike one side instead of the centre (see Fig. 47).

A prominent distinction between the Hurdy-gurdy wheel and the Partial Turbine rests in the fact that the former has "open" and the latter "closed" buckets. When properly constructed the one is no more an "impact wheel" than the other.

The principal sources of loss in Hurdy-gurdy wheels are in general:

1st. The energy remaining in the water after being discharged from the bucket.

2d. The heat developed by impact of the water in striking the bucket.

3d. The fluid friction of the water in passing over the surface of the bucket.

4th. The loss of head in the nozzle. The loss in the supply pipe is not charged to the wheel.

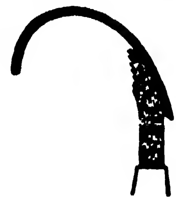


Fig. 47.

5th. The journal friction.

6th. The resistance of the air.

In the formulas below all of these sources of loss but the first are neglected; and for the purpose of weighing the importance of curvature in the buckets, it is assumed that all of the water escapes from the bucket with the same velocity—*i.e.*, no water is "carried" with the wheel.

Let c designate the velocity of the bucket in feet per second.

" v " " velocity of the jet escaping from the nozzle.

" u " " relative velocity of discharge from the bucket.

" w " " absolute velocity of discharge from the bucket.

" Q " " quantity of water supplied per second in cubic feet.

" γ " " weight of one cubic foot of water.

" L " " useful work (in foot lbs. per second) under the above conditions.

" η " " efficiency of the wheel under the above conditions.

" g " " acceleration of gravity.

" δ " " angle made by the discharge end of the bucket with its line of motion (see Fig. 48).

Then $u = v - c$

$$w^2 = u^2 + c^2 - 2uc \cos \delta = v^2 - (2vc - 2c^2)(1 + \cos \delta)$$

$$L = \frac{Q\gamma}{2g}(v^2 - w^2) = \frac{Q\gamma}{2g}(2vc - 2c^2)(1 + \cos \delta)$$

$$\eta = \frac{L}{\left(\frac{Q\gamma}{2g}\right)v^2} = 2(1 + \cos \delta)\left(\frac{c}{v} - \frac{c^2}{v^2}\right)$$

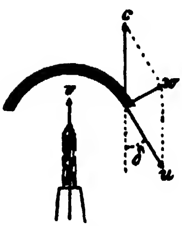


FIG. 48.

And by varying the velocity of the bucket we have for the greatest efficiency—

$$\frac{d\eta}{dc} = 2(1 + \cos \delta)\left(\frac{1}{v} - \frac{2c}{v^2}\right) = 0$$

$$c = \frac{v}{2} \qquad (1)$$

i.e., the velocity of the bucket should be one-half the velocity of the supply water (the jet) escaping from the nozzle, and this is not very materially modified by introducing the other conditions. Hence the greatest efficiency—

$$\eta_1 = \frac{1}{2}(1 + \cos \delta) \qquad (2)$$

The smaller we make δ the greater will be this efficiency.

Flat Buckets.—If the bucket is flat, $\delta = 90$ degrees, hence $\eta_1 = 50$ per cent.; *i.e.*, 50 per cent. could not be reached with flat buckets, on account of the sources of loss neglected in these formulas.

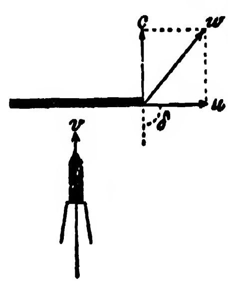


FIG. 49.

A series of experiments were made with such flat buckets (see Fig. 50) with a ⅜-inch nozzle.

The curve of efficiency for various speeds, as established from these experiments, is shown

in Fig. 56. A ¼-inch nozzle gave results but slightly differing from these.

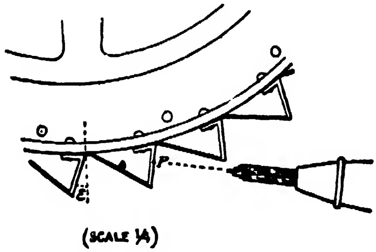


FIG. 50.

The highest result was 40.4 per cent. under 50.2 feet head.

The velocity of the jet being approximately $v = .98 \sqrt{64.36 \times 50.2} = 55.7$ feet per second, we should have for best efficiency, if the conditions were such as led us to equation (1), the velocity of point P of the bucket $c = \frac{v}{2} = 27.85$. This corresponds to 6.8 revolutions of the wheel per second, which is marked by a heavy vertical line crossing the curve very near the point of the best efficiency actually obtained.

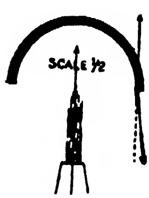


FIG. 51.

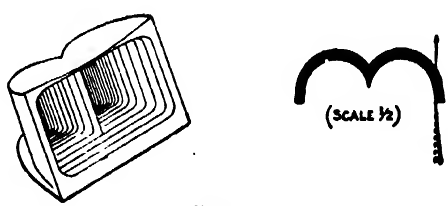


FIG. 52.

Curved Buckets.—If δ could be made $= 0$, we should have, under our assumed conditions, $\eta_1 = 100$ per cent.; w would be $= 0$, and the water would simply fall from the bucket by its own weight. Evidently, then, δ should

be made as small as is compatible with clearance of the supply jet and the following bucket. Experiments were made with such a bucket as shown in Fig. 51 in section, in other respects shaped and set upon the rim of the wheel as the Pelton bucket (see Fig. 53).

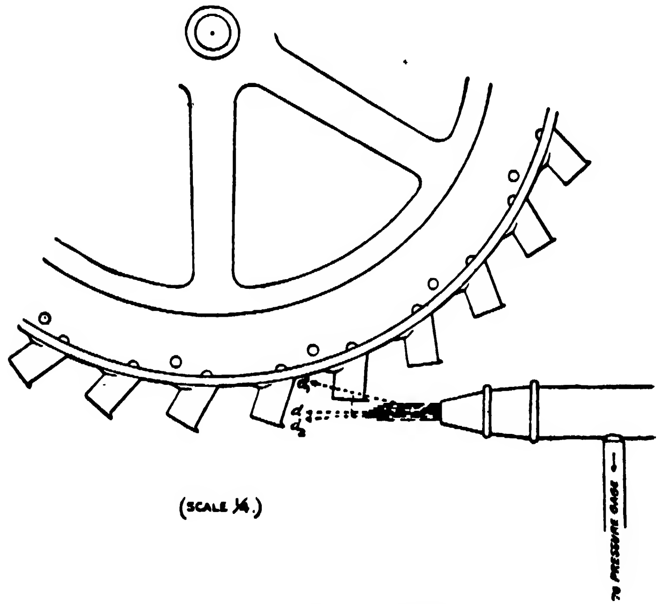


FIG. 53. PELTON WHEEL.

A 3/8-inch nozzle was used under head of 50.4 feet. The best result reached was 65.6 per cent. The curve of efficiency is shown in Fig. 56. The heavy line crossing the curve again shows the best speed as calculated by making $c = \frac{v}{2}$. This marks a speed about one-half revolution per second greater than that actually found by experiment.

The Pelton Wheel.—Mr. Pelton kindly furnished a pattern from which buckets were cast, and thirty of them attached to the wheel as shown in Fig. 53. A

section and an isometric projection of the bucket are shown in Fig. 52. The angle δ is just sufficient to provide against interference of the discharged water with the buckets following.

The face of the bucket is inclined to the diameter of the wheel.

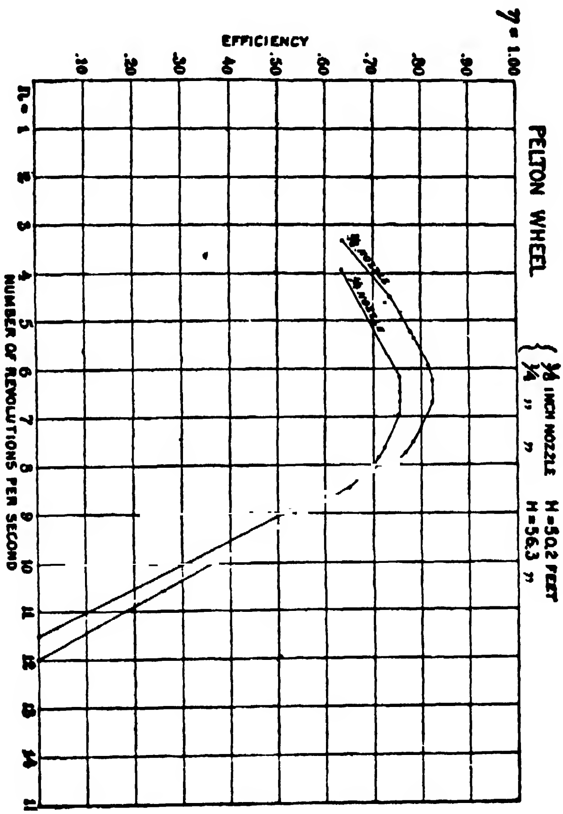


FIG. 54.

Experiments were first made with seven differen settings of the nozzle. For direction d_1 (Fig. 53) of jet the efficiency was 68.1 per cent., for d 80.5 per cent., for d_2 78.4 per cent. The nozzle was permanently set to give direction d to the jet.

The efficiency was then determined for various velocities of the wheel:

1st. With a ⅜-inch nozzle giving 82.5 per cent. as best result (see Figs. 54 and 56).

2d. With a ¼-inch nozzle giving 75.6 per cent. as best result (see Fig. 54).

3d. With a $\frac{7}{16}$-inch nozzle giving 82.6 per cent. as best result. *

Doubtless the nozzle might have been increased to ½ inch without materially reducing the efficiency.

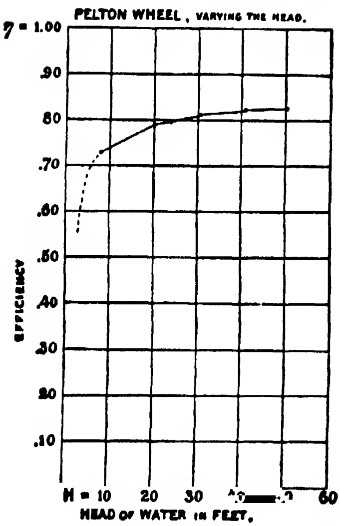


FIG. 55.

Another set of experiments was made with the ⅜-inch nozzle under various heads, from 50 feet down to 8 feet, showing a gradual decrease in useful effect (see Fig. 55).

At 8 feet the efficiency still remained as high as 73 per cent. In experimenting with the "curved buckets" the efficiency might possibly have been raised 2 or 3 per cent. by attending more carefully to the curve and to the size of nozzle used. Still there was probably a gain of more than 12 per cent. due to the introduction of the wedge in the Pelton bucket.

In comparing the three Hurdy-gurdy wheels experimented with, it is evident from Figs. 52, 46, and 45 that the "Pelton bucket" will "carry" the least, and the "curved bucket" the greatest, quantity of water. This

* In view of the fact that Mr. Pelton claims a still higher efficiency for his wheel, it should be stated that although he furnished the pattern for the bucket, the wheel does not precisely conform in all particulars to his standard.

"carried" water is the most important of the sources of loss not taken into account in equations (1) and (2). Hence the approximate best speed as calculated from equation (1) differs least from the actual best speed as found by experiment, in the case of the "Pelton bucket," and most in the case of the "curved bucket" (see Fig.

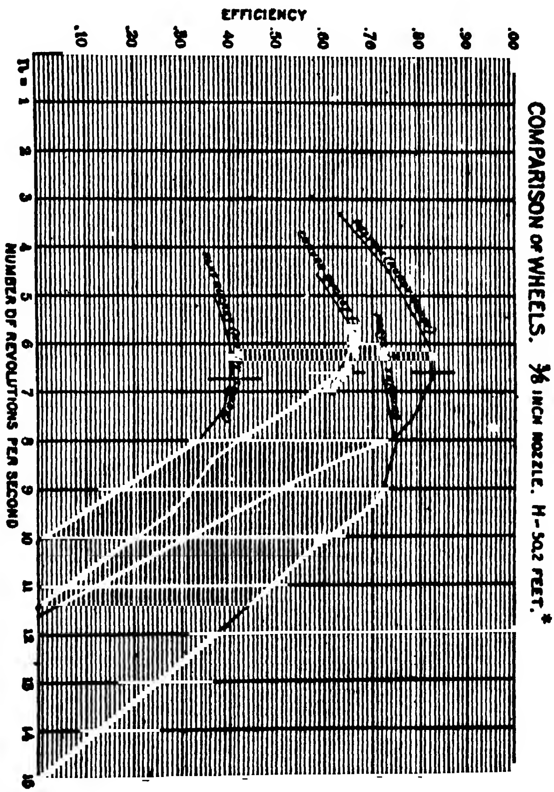


FIG. 56.

56). It is perfectly safe to say the Pelton bucket should have one-half the speed of the supply jet for best effect.

It is plain that the Pelton wheel has certain advan-

* The Partial Turbine here mentioned is a Tangential Wheel with inner feed, and was specially designed for a small supply jet.

tages over the Tangential wheel. It is more easily built, has a decided advantage in the setting of the nozzle, and is not so dependent on the precise size of nozzle used. The capacity of these wheels may be doubled by adding another nozzle.

It is quite likely that a wheel considerably larger than the one used at the University could be made to give a still higher efficiency than the 82½ per cent. found. The angles in the pattern for bucket castings could be made more accurate.

THE PAN.

The pan, an indispensable companion of the gold-miner, is pressed from a single piece of Russia sheet iron. It is 12 inches in diameter at the bottom and 15 to 16 inches on the top, the sides inclining outward at an angle of about 30 degrees, and turned over a wire around the edge to strengthen it. It is used in prospecting, cleaning gold-bearing sand, collecting amalgam in the sluices, and, in fact, in every branch of the business.

Its proper manipulation for washing dirt requires a certain skill, which can be acquired only by practice. The pan, filled with dirt, is submerged in a tub or pool of water and the gravel worked with the hands until all cemented material is disintegrated. The coarse stones are cleaned and thrown out. In washing the residue the pan is held in a tilted position. By a circular motion and by careful use of the water, into which the pan is continually dipped, all the lighter dirt is worked to the top and over the edge (pebbles being picked out by hand) until only the fine gold and black iron sand remain.

THE BATEA.

The batea is a shallow wooden bowl commonly used in Brazil and the Spanish-American States for separating, on a limited scale, grains of gold from sand, pyritic matter, and magnetic iron. "A disc of 17 inches diameter,

being turned conical 12 degrees, will have a depth of 1⅞ inches from centre to surface. The thickness may be ⅝ of an inch. The outer edge, perpendicular to axis, will require wood 2½ inches thick for its construction. The best wood is Honduras mahogany." *

THE ROCKER.

The rocker is a box 40 inches long, 16 inches wide on the bottom, 1 foot high, with sides sloped like a cradle, and with rockers at the middle and back end.

The upper end is a hopper, 20 inches square, 4 inches deep, with a perforated iron bottom with half-inch-diameter holes. This top hopper is removable. Under the perforated plate there is a light frame, placed on an incline, upon which a canvas apron is stretched, forming a riffle.

In washing with the rocker the material is thrown into the hopper and water is poured on with a dipper held in

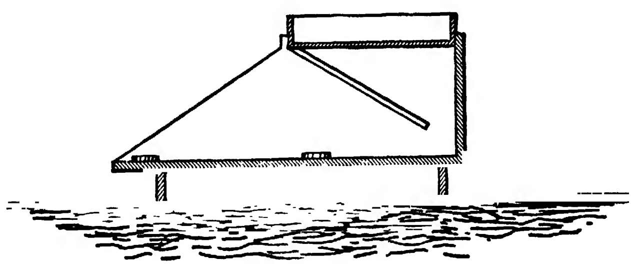


FIG. 57. THE ROCKER.

one hand, while with the other hand the cradle is kept rocking. The water washes the sand and dirt through the bottom of the hopper, and the gold or amalgam is either caught in the apron or picked up in the bottom of the rocker, while the sand and lighter material are discharged at the end, and the coarse material in the hopper is thrown aside. In California rockers were extensively used before the introduction of ditches, but now they

* See paper by Melville Attwood, "Transactions Cal. State Geological Soc."

are employed only when cleaning up placer claims and quartz mills, for the collection of finely subdivided particles of amalgam and quicksilver.

THE TOM.

The tom, said to have been an importation from Georgia, was first used in Nevada County in the latter part of 1849. It is a rough trough about 12 feet long, from 15 inches to 20 inches wide at the top, 30 inches wide at the lower end, and 8 inches deep. It is supported on timbers or stones, and set on an incline of, say, 12 inches

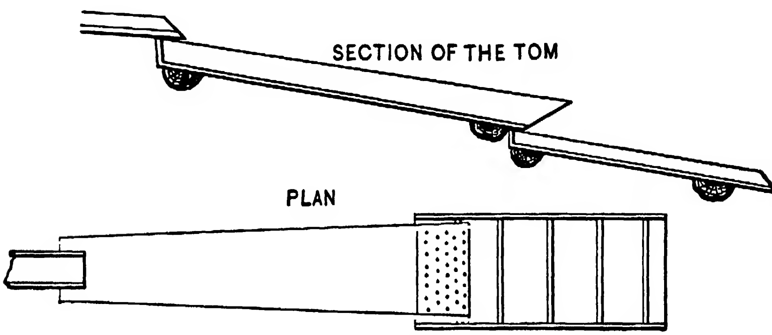


FIG. 58. THE TOM.

(or 1 inch per foot). A sheet-iron plate, perforated with holes half an inch in diameter, forms the bottom of the lower end of the trough, which is bevelled on the lower side, so as to have the plate on a level.

The material, when fed in from sluices, on striking the riddle (or perforated plate) is at once sorted, the fine dirt with the water passing through it, while the coarser stuff is shovelled off.

Under the perforated plate there is a flat box set on an incline, into which the finer gravel passes. By the continual discharge of the water through the plate, and with the occasional aid of the shovel, the sand is kept loose, allowing the gold to settle. Since the introduction of sluices the tom has disappeared.

THE PUDDLING BOX.

The puddling box is a wooden box, usually 6 feet square and 18 inches deep, arranged with plugs for discharging the contents. The box is filled with water and clayey dirt containing gold. By continuous stirring with a rake the clay is dissolved in the water and run off. The concentrated material collected in the bottom is washed subsequently in a pan or rocker. The puddling box has been used to a very limited extent in California, but in Australia, according to Forbes, no less than 3,950 of them, worked by horse-power, were in use in Victoria alone in 1860.*

AMALGAM KETTLES.

The amalgam and quicksilver kettles are ordinary sheet-iron buckets or porcelain-lined iron kettles. In cleaning up they are especially used as receptacles for floating the gold amalgam. The amalgam, previous to straining and retorting, is floated in quicksilver in order to free it of all foreign substances.

* J. R. Forbes, "Mining and Metallurgy of Gold and Silver."

CHAPTER XIII.

BLASTING GRAVEL BANKS.

WHERE the deposits are very strongly cemented blasting is necessary.

The ordinary method of blasting gravel banks is as follows: A drift is run in from the face on the bottom of the deposit a distance proportionate to the height of the bank (as a general rule not over three-quarters of this for high banks) and the character of the ground to be moved. From the end of this drift a cross drift is driven each way (forming a T). The cross drift is charged with kegs of powder, the main drift is securely tamped by filling it up solid with the material which has been extracted, and the powder is exploded by means of a time fuse or an electric battery. In some instances when the ground is "heavy and bound" several cross drifts are used The amount of powder used is determined by the position, character, and height of the bank, a quantity sufficient only to shatter the ground being employed.

Blast at Smartsville.—The following details of several large blasts are given as illustrating the general facts. A blast of 450 kegs of black powder was made at Smartsville in hard cement with an 80-foot bank, the ground being ordinarily bound (*i.e.*, with two sides free). The main powder drift was run in from the face of the bank 85 feet, cross drifts being opened each side 40 feet and 85 feet from the mouth. Each cross drift was 45 feet long, and from its ends and centres two "lifters" were driven at right angles to it, extending respectively half way to the next cross drifts and to the face of the bank. After charging the cross drifts the main drift was tamped and the powder exploded by means of an electric battery.

The arrangement of the powder chambers for a 1,201-keg blast made by the Smartsville Hydraulic Mining Company in December, 1868, is shown in the following diagram.

X was a shaft 74 feet deep, from the bottom of which the main drift, A, was driven 185 feet. The cross drifts, B, three in number, were driven at distances respectively of 70 feet, 120 feet, and 170 feet from the shaft, X. They extended each 20 feet on one side of the main drift and 40 feet on the other side. The several drifts marked C are called "lifters." Each "lifter" was 15 feet long. The total length of the drifts aggregated 570 feet. They were 2½ feet wide and 3½ feet high. The cross drifts were charged with 1,201 kegs (25 pounds each) of black powder. The main drift was securely tamped from the shaft to the first cross drift, a distance of 70 feet. The powder was simultaneously ignited by electricity at 12 different points.

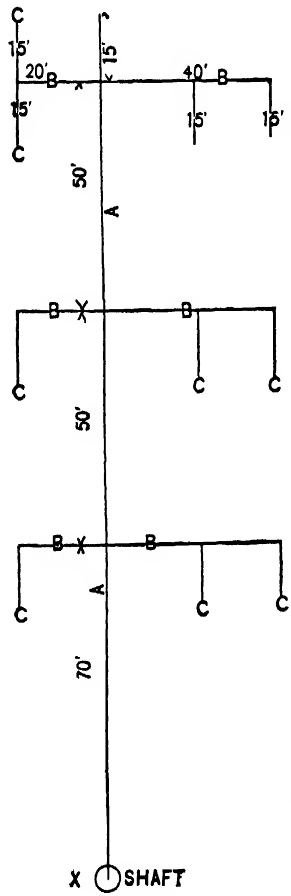


Fig. 59.

The ground moved was 270 feet long, 180 feet wide, with an average depth of 100 feet. The cost of the blast was about $6,000.

Blue Point Blast.—A large blast of 2,000 kegs (25 pounds each) was exploded December 29, 1870, at the Blue Point Mine, Sucker Flat, Nevada County. The main drift

was 325 feet long. Commencing at the upper end of the drift, a cross drift was run 80 feet to the right and 120 feet to the left. Five additional cross drifts of similar length were driven from the main drift 50 feet apart, the last one being opened at a point 75 feet distant from the entrance of the tunnel. There were three lifters in this last cross drift, two in the left arm and one at the end of the right arm. The main drift was tamped from the entrance to the first cross-drift. The drifts were 3 by 4 feet in size. The blast was simultaneously fired at ten different points by electricity. The mass shattered was reported as 200 feet long, 150 feet wide, and 73 feet deep.

At the Enterprise Mine, Nevada County, with 250 feet bank, a blast of 1,700 kegs was fired.

Paragon Mine Blast.—In 1874 there was a blast of 700 kegs black powder set off at the Paragon Mine, Placer County. The details of the drifts arranged for the blasts are shown in Fig. 60.

The main drift, A, was tamped for 75 feet from the near end, and the cross drifts tamped 10 feet each way, a space being left in the lifters for the expansion of the gas generated by the explosion of the powder. The drifts were 4½ feet high and 5 feet wide, and the bank was 150 high. The blast was fired by electricity, and the ground covered by the drifts was thoroughly shattered.

A blast of 3,500 pounds of giant powder No. 2 was fired, in 1872, in the Harriman and Taylor claim at Gold Run, Placer County, and is reported to have thrown down 200,000 cubic yards of gravel.

Dardanelles Mine Blast.—At the Dardanelles Hydraulic and Drift Mine near Forest Hill, Placer County, a blast was made with 36,400 pounds of Judson powder (old), shattering about 500,000 cubic yards of cement gravel. The gravel bank had a face of some 1,200 feet in length, with a height of 175 feet. This deposit reposed on a rising bed-rock. Five parallel drifts, 180 feet apart, were run in from the face a length of 70 feet each. From the

end of each of these drifts two arms (right and left) or cross cuts were driven 70 feet long, thus leaving a space of 40 feet between the ends of the cross cuts from the several main drifts. The powder, in 50-pound boxes, was charged in lots of 1,000 to 1,500 pounds in the different chambers. In each chamber three exploders were placed

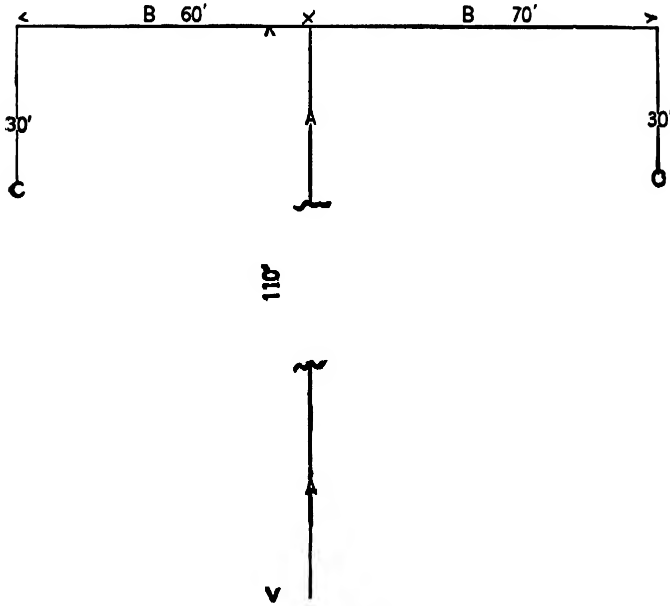


FIG. 60.

in the powder, each exploder being carefully connected by an insulated copper wire with the main wires on the outside of the drifts.

The drifts were all well tamped with clay and boulders. The wires from the exploders connected outside of the main drifts with two copper wires from an electro-magnetic battery which was situated to the right and about 200 feet from the face of the bank. When everything was ready (November 8, 1879) the blast was fired. The back ground was raised bodily 4 or 5 feet, and the face was thrown forward.

At the Blue Tent Mine, Nevada County, in 1880, a bank 200 feet high was thrown down with 43,000 pounds of powder.

Blasting Powder.—Common blasting powder was almost universally used up to 1876. Since that time Judson powder has been introduced, and combinations of black blasting powder and Giant powder also have been experimented with. Giant powder is extensively used for breaking up lava, pipe-clay, boulders, trunks and stumps of trees, for all of which purposes it is found to be very efficient.

Methods of Blasting.—In certain districts it is customary to wash off the top or lighter gravel and subsequently blast the bottom cement. For this purpose shafts 15 to 20 feet deep are sunk to the bed-rock, and a small chamber is excavated at the bottom. This chamber is charged with a few kegs of powder and tamped, and a blast is fired by means of a fuse.

The want of proper information concerning the use and application of powder to bank-blasting has undoubtedly caused a great waste of explosives, and the subject is well worthy of investigation with a view to future improvement.

In blasting gravel banks it is desirable to thoroughly shatter the material. To accomplish this purpose one must be governed by the character of the ground in the selection of the powder. In hard cemented deposits quick powders like the Judson (a low-grade nitroglycerine powder) and the Vulcan B B are found to work better than black powder; while the latter does fully as much work in softer ground, a slow-lifting powder is in such cases all that is requisite.

With very high banks it is more economical to blow out the bottom and not attempt to raise the superincumbent mass. The charge should be placed so that the line of least resistance is horizontal.

With banks from 50 to 150 feet high, and likewise in

cement gravel of ordinary tenacity, the following method has been found to give excellent results.

The main drift should be run in a distance of two-thirds the height of the bank to be blasted. The cross drifts from the end of the main drift should be driven parallel with the face of the bank, and their lengths determined by the extent of the ground which is to be moved. A single T is all that is necessary.

The minimum amount of powder required is from 10 to 20 pounds per 1,000 cubic feet of ground covered by the drifts. The quantity used necessarily varies with the character of the gravel. When the banks are strongly bound or the gravel is very tenacious the quantity must be increased. Small blasts, everything else being equal, require a larger amount in proportion to the ground than large ones, varying in practice from 10 to 50 pounds for each 1,000 cubic feet. It is usually expected that a blast will prepare nearly double the quantity of the ground covered by the drifts.

The annexed table is a record of all the large bank blasts fired on the Milton Mining and Water Company's property at Manzanita Hill, Sweetland, Nevada County, during a period of three years. These blasts were made under the immediate direction of Richard Thomas, foreman.

The top gravel had been previously washed off, leaving banks from 50 to 150 feet in height. The gravel is usually hard, and cemented for 50 feet (rarely higher) from the bottom. Above this cemented material the gravel is comparatively soft and easily broken, and therefore the amount of powder employed is proportionately lessened as the banks increase in height.

From the appearance of the ground subsequently washed it was estimated that 225 to 230 cubic feet were shattered per pound of powder exploded.*

* "Report upon the Blasting Operations at Lime Point, California, by Lieutenant-Colonel G. H. Mendell, Corps of Engineers, U. S. A.," gives interesting details of large blasts in rock formation.

TABLE XXIV.

Bank Blasting at the Manzanita Mine, Sweetland, Nevada Co., Cal.

Date.	A Height of Bank.	B Main Drift.	C Length of T's.	A × B × C Cubic feet of Ground.	Pounds of Powder.	Pounds of Powder per 1,000 cub. ft. of Ground.
	Feet.	*Feet.*	*Feet.*	*Cubic feet.*	*Lbs.*	*Lbs.*
February, 1879..	67	65	124	550,000	6,750	12.27
March, " ..	56	36	86	173,000	2,150	12.43
" " ..	107	90	151	1,454,000	15,250	10.50
" " ..	90	42	56	212,000	2,000	9.43
April, " ..	83	75	82	510,000	5,500	10.78
May, " ..	86	74	114	725,000	8,550	11.80
June, " ..	70	56	169	662,000	8,500	12.77
" " ..	100	83	159	1,304,000	16,000	12.27
July, " ..	80	61	82	400,000	5.300	13.25
August, " ..	78	66	117	602,000	10,500	17.44
September, " ..	55	46	79	200,000	4,000	20.
" " ..	40	46	66	121,000	2,000	16.52
" " ..	82	70	124	712,000	11,250	15.80
October " ..	70	53	113	419,000	7,000	16.70
January, 1880..	35	44	$72\frac{8}{10}$	111,000	2,000	18.
" " ..	60	60	80	288,000	5,100	17.70
February, " ..	30	$76\frac{8}{10}$	80	183,000	3,100	16.94
April, " ..	85	83	138	973,000	14,500	14.90
" " ..	70	44	55	169,000	3,250	19.22
May, " ..	95	79	114	855,000	16,250	19.
June, " ..	16	41	42	27,000	625	22.72
" " ..	60	57	98	355,000	5,625	16.80
" " ..	70	71	139	691,000	13,000	18.81
July, " ..	60	54	106	343,000	6,300	18.37
" " ..	45	51	90	206,000	4,500	21.79
August, " ..	85	75	155	988,000	14,500	14.67
September, " ..	70	66	136	628,000	12,000	19.11
November, " ..	50	56	109	305,000	5,000	16.39
" " ..	80	78	150	936,000	13,500	14.42
December, " ..	100	105	128	1,344,000	18,750	14.
March, 1881..	100	87	163	1,418,000	14,000	9.87
April, " ..	90	90	165	1,336,000	14,000	10.47
" " ..	35	40	62	87,000	2,500	28.74
May, " ..	90	69	89	553,000	8,750	15.82
" " ..	95	80	126	958,000	13,750	14.35
June, " ..	110	89	148	1,449.000	17,500	12.08
" " ..	57	61	79	275,000	3,800	13.80
July, " ..	65	65	145	613,000	8,000	13.05
" " ..	110	63	97	672,000	9,500	14.13
August, " ..	45	52	67	157,000	3,350	21.33
" " ..	100	89	157	1,397,000	16,000	11.45
" " ..	85	81	132	909,000	13.000	14.30
September, " ..	100	45	93	418,000	5,000	11.96
" " ..	100	80	128	1,024,000	15,000	14.65
October, " ..	90	76	127	869.000	13,000	14.96
" " ..	100	54	124	670,000	8,000	11.94
November, " ..	70	63	101	465,000	6,500	14.
" " ..	70	57	45	180,000	6,500	36.11
" " ..	45	50	90	202,000	4.500	22.27
Totals.........	3,632	$3,194\frac{8}{10}$	$5,352\frac{8}{10}$	30,098,000	425,400	....
Averages......	$74\frac{1}{10}$	$65\frac{2}{10}$	$109\frac{2}{10}$	....	....	14.13
February, 1883..	190	65.5	123	1,530.735	9.500	6.20
March, " ..	190	81	136	2,093,040	14,000	6.68

In the blasts here recorded Judson powder chiefly was used, only a small proportion being Black powder and Vulcan B B.

Firing by Electricity.—The firing of blasts by means of electricity requires that great care should be taken of the wires while tamping, and where dynamite exploders with platinum wires are used the "compound circuit" is most desirable. A paper entitled "On the Simultaneous Ignition of Thousands of Mines," by Julius H. Striedinger, published in the "Transactions" for June, 1877, of the American Society of Civil Engineers, contains much valuable information on the subject.

In charging the drifts the powder (in boxes or kegs) is piled up in rows; two wires, A A and D D (see Fig. 61),

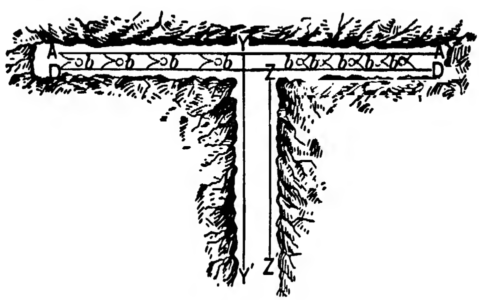


FIG. 61.

extend along the middle row, the tops of the boxes on which wires rest being removed. The exploders, *b*, *b*, *b*, are inserted in giant-powder cartridges and placed on top of the paper covering the powder.

The wires A A and D D are then connected with the wires Y Y′ and Z Z′, which extend to the battery.

Tamping.—Great care should be used to prevent the "blowing-out" of the tamping, which results not only in considerable loss of effect, but often causes great destruction to property and even to life. It is advisable, when firing blasts by fuse, to tamp nearly the entire main drift. The gravel extracted from the drift is used for this purpose, and should be fairly dry and as free as possible from large stones, which cause great damage in case

of a blow-out. The tamping must be firmly rammed by wooden mauls, so that it will not settle from the roof of the drift. In order to guard against failure through defective fuse it is customary to use two or three lines, which are simultaneously ignited.

Firing by electricity has the advantage of requiring less tamping and of permitting it to be placed in the cross drifts between the two chambers of powder, which are simultaneously fired—a result that could not be effected by fuse. The force from the explosion from the two chambers, acting upon the tamping from opposite sides, prevents its being blown out; and therefore when drifts are fired in this way it is necessary to tamp but a short distance in the cross drifts and but a few feet in the main drift.

Owing, however, to the many failures arising from defective batteries and connections, the miners generally have abandoned the use of the electric battery.

CHAPTER XIV.

TUNNELS AND SLUICES.

Tunnels.—Tunnels are run for the purpose of opening gravel claims (where open cuts are impossible on account of the formation of the ground), and also to afford proper facilities for removing the washed material.

A tunnel should be driven well into the channel before any connection is made with the surface.

Shafts for Tunnels.—The shaft which connects with the headings should be vertical, though in some cases inclines have been used. Its size is determined by the requirements of the work, and varies, for ordinary cases, from 3 by 3 feet to 4½ by 9 feet in the clear. When raising from the tunnel due precaution should be taken against accidents arising from the rush of water, sand, and gravel, which is liable to occur on tapping the bottom of a deposit. A shaft 4½ by 9 feet should be divided into two compartments, one of which will serve as a man-way. A compartment 4 by 4 feet in the clear is ample for the water-way.

It may be noted that a vertical shaft, when properly timbered, is the most desirable and economical for opening hydraulic claims, and with drops of 300 feet no trouble has been experienced. There is no difficulty in connecting directly with the tunnel where the work is done well and the mine properly opened. But where washing is going on through a shaft into a tunnel in process of extension, it is convenient to have the shaft located at one side and connected with the tunnel by a short drift. By this means the work in the tunnel can progress while the washing is carried on.

Shaft Timbering.—Where a shaft is in hard rock, and no man-way is needed, timbering is unnecessary; but in soft rock or gravel, to avoid any accident or delay the shafts should be strongly timbered, closely lagged, and lined on the inside with blocks (6 to 10 inches thick) to within 8 to 30 feet of the surface, the depth being dependent on the softness of the gravel. This top, being the first washed off, thereby gives the initial grade for the ground sluices. As washing proceeds the upper lining and timbers are removed to enable the material to be drawn into the shaft. A shaft in hard rock can be partitioned for a man-way with stoll-timbers firmly wedged and blocked.

No extraordinary precaution is required for the protection of the bottom of the shaft, the material washed being allowed to drop directly on the bed rock, where it soon wears a hole, in which the large stones from the mine lodge and form a pavement. At the junction of the shaft and the tunnel the latter should be increased in height at least 50 or 75 per cent.

Second Shaft.—With long tunnels it is advisable to sink a second shaft at a convenient distance from the heading. Formerly, as a precautionary measure, a man was placed in the tunnel to watch the washings, and in such cases a second shaft was indispensable. It is now customary, when washing into a shaft, to provide a swinging door over the sluice, about 75 feet below its head, and connected by chain and ropes to a signal on top of the shaft which gives the pipe-men notice in case of overflow.

Should an accident occur at the main shaft by its caving or closing up, the second shaft might afford the necessary facilities for continuing the work. When a line of pipe is carried down the second shaft for the purpose of assisting in opening the closed one, great precaution must be used in piping, particularly if the closed shaft is filled with water. When this expedient has to be resorted to it is usual to place the pipes in position and withdraw the

workmen before the water is turned on; and if the blockade is not broken in a reasonable time the water is shut off, men go down and extend the pipes nearer the blockade, and again the water is turned on, and the operation is continued until the blockade is broken. If the shaft or tunnel is closed by gravel mixed with heavy boulders it is necessary often to employ powder.

First Washing.—The first washings through a shaft should be done with care, and the surface within as great a radius as can be conveniently washed and drawn should be cleared on all sides before taking off the top timbers. Attempts to push this preliminary work have frequently caused an over crowding of the shaft, resulting in its filling up or caving. It is therefore essential that the gravel should be run so as to avoid the rush of material from caves.

Size of Tunnel.—The size of the tunnel is generally dependent on the size of the sluice. It is usually driven 2 to 3 feet wider than the inside width of the sluice, and 7½ to 8 feet high. These proportions permit the proper construction of the sluice and give sufficient room for the blocks and for the workmen when cleaning up. The grade depends on the topography of the country.

Location of Tunnels.—In locating the mouth of a drainage tunnel (or of an open cut) that point is to be selected from which the sluices, running on the most direct practicable line, with a given grade, can bottom the maximum extent of the "pay channel" at the smallest expense. Due regard should be had to the dump, and allowances made for contingencies arising from changes, such as depressions and holes in the bed-rock.

Where the bed-rock disintegrates on exposure to the air an extra allowance for depth is advisable. This additional depth is a matter of judgment, and is regulated by the character and peculiarities of the bed-rock, extent of ground to be worked, and the position of the shaft. It is always possible to "ease up" the grade; but if the main

line of drainage is once fixed and proves to be too high, it is a source of endless expense, frequently fatal to the enterprise. Many instances could be cited where, for want of properly conducted preliminary investigations, tunnels have been driven on too high a level and thereby the enterprises have resulted in failures.

At the Pioneer Mine, Grass Flat, Plumas County, the original owners in opening their claim ran a tunnel 4,000 feet long. When midway in the channel the tunnel was found to be 22 feet above the bed-rock. The sum of $60,-000 expended in this work was a total loss, and the subsequent purchasers were obliged to expend over $100,000 in properly opening the mine.

SLUICES.

The name "sluice" was originally applied by the miner to the sluice box. Subsequently several sluice boxes were joined together for permanent washing, and the word "flume" was used synonymously. The word *sluice* used in the text refers only to troughs, cuts, or boxes in which or through which gravel or dirt is washed, in contradistinction to the term *flume*, which is applied solely to wooden structures used for water conduits.

To secure the maximum discharge sluices should be set on straight lines so far as possible, and where curves occur the outer side of the box should be slightly raised, in order to cause a more general distribution of the materials over the riffles. When lines of sluices have frequent curves it is customary to make no changes in the grades, although to secure the greatest flow of material doubtless provision should be made to overcome retardation by increased grades at and below the curves. Sluices with drops are highly desirable for saving gold.

Grade.—The facility with which gravel can be moved depends mainly on the inclination which is given to the

sluices. The question of grade is therefore one of vital importance, and to properly investigate and determine this point great care and skill are requisite. When the topography of the country admits of unlimited fall the grade upon which the sluices are set should be regulated by the character of the gravel. Where the wash is coarse and cemented, requiring blasting, or where there is much pipe-clay, a heavy grade is necessary. Strongly cemented gravel requires drops to break it up.

General Grade Adopted.—Experience thus far has led to the adoption in most localities of what is called a 6 or 6½-inch grade, meaning 6 or 6½ inches to the box 12 feet long, or, say, a 4 to 4½ per cent. grade. In some places, where large quantities of pipe-clay are washed off, 9 and 12-inch grades to the box are used (6 to 8 per cent.) In others, on account of natural obstacles encountered, a 1½ per cent. grade, or 2½ to 3 inches per box of 16 feet, is used.

Light gravel containing clay or earthy matter can be moved on an easier grade and with less water than heavy gravel; nevertheless, when a 4½ per cent. grade can be obtained it is desirable, as it lessens the labor of handling rocks and more material can be washed. Moreover, as light gravel is generally poor in gold, this deficiency can be made up only by washing large quantities. Light gravel requires that the water should be run with sufficient force to carry off the rocks washed through the sluice, and yet be in only sufficient volume to prevent the packing of black and heavy sand. If too much water is used by superincumbent pressure the sand drops and packs the riffles.

The best results are obtained with shallow streams on light grades. Coarse gravel demands from four to seven per cent. grades and a proportionate increase of water. In washing this heavy material the water in the sluice should be deep enough (10 to 12 inches) to cover the largest boulders ordinarily sent down.

As a larger volume of water is sent through a sluice running heavy cement gravel, more material can be transported and washed if a proper proportion of light and heavy gravel is made. The rocks and cement, as discharged into the sluices, keep the sand stirred and prevent its packing, while the cement, rolling along the sluice, is disintegrated.

At Forest Hill Divide some of the mines use a grade of 10 to 24 inches per 12 feet. The reason for this excessive grade is the scarcity of water and the heavy material, it being necessary to run rocks as large as can pass through a four-foot flume.

Size of Sluice.—The size of the sluice depends on the grade, character of the gravel, and quantity of water to be used. A sluice 6 feet wide and 36 inches deep on a 4 or 5 per cent. grade will suffice for running 2,000 to 3,500 inches of water. One 4 feet wide, 30 inches deep, on a grade of 4 inches to 16 feet, will suffice for 800 to 1,500 inches of water, and on a 4 per cent. grade it is large enough for 2,000 inches. A sluice 3 feet wide and 30 inches deep, with a 1½ per cent. grade, is suitable for 600 to 1,000 inches.

As to the length, the principle is to construct the line sufficiently long to insure the most complete disintegration of the material, affording ample surface for the grinding of the cement, and the best facilities for the gold to settle in the riffles. The length of the sluice employed should be governed by its yield, the rule being to keep extending the sluice so long as the yield exceeds the expense.

Details of Construction.—Sluices of a width of 4 feet and upward are made of 1½ or 2 inch plank, with sills and posts of 4 by 4 or 4 by 6 inch scantling. To guard against leakage of quicksilver it is important that the bottom should be tight. To secure this the bottom planks should be of half-seasoned lumber, free from knots, and the joints grooved and a dry, soft pine tongue in-

serted. The bottom and sides are spiked together generally with nails four inches apart. It is not necessary to plane either the bottom or side planks. In many cases the planks are simply fitted well and closely nailed together.

The sills are placed from 3 to 4 feet apart, depending upon the size of the scantling used, which is regulated by the width of the sluice; thus a 4-foot sluice would require a sill 7 feet long, of 4 by 6 or 4 by 4 inch stuff. The posts are halved into the sills and firmly spiked, and every second or third post should be supported by an angle brace. The bottom planks should be solidly secured to the sills by a liberal use of heavy spikes. The bottom of a new sluice is liable to be raised by the pressure of the water which collects under it and finds no discharge. To avoid this the flume should be heavily weighted down by loading the ends of the sills with stones. In tunnels the ends of the sills can be held down by braces extending to the rock overhead.

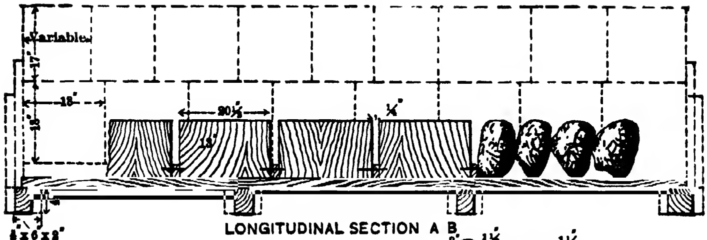
North Bloomfield Tunnel Sluice.—The annexed diagrams give the detailed construction of the tunnel sluice box used at the North Bloomfield Mine. The box is 6 feet wide and 12 feet long, with sides 32 inches deep.

To each sluice box are used:

8 Posts................	4 inches ×	6 inches ×	3 feet 2 inches.
4 Sills..................	4 "	× 6 "	× 8 "
3 Bottom planks.........	2 "	× 24 "	× 12 "
4 Side planks...........	1½ "	× 16 "	× 12 "
2 Top rails..............	2 "	× 8 "	× 12 "
16 Braces................	2 "	× 4 "	× 2 "

On the outside of the tunnel the sills and braces are longer. The nails for the bottoms are 30*d.*, for the sides 20*d.* The side lining, composed of worn blocks when available, is 3 inches thick, 18 to 20 inches deep, and is set 2½ to 3½ inches above the bottom. The riffle strips, between the blocks, are 1¼ by 3 inches and 5 feet 11½ inches long. The blocks are 13 inches deep and 20½ inches square, and average about 19 to the box. Where

Fig. 64.



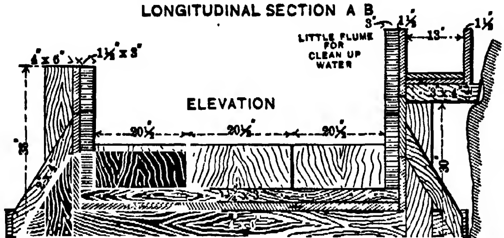


Fig. 63.

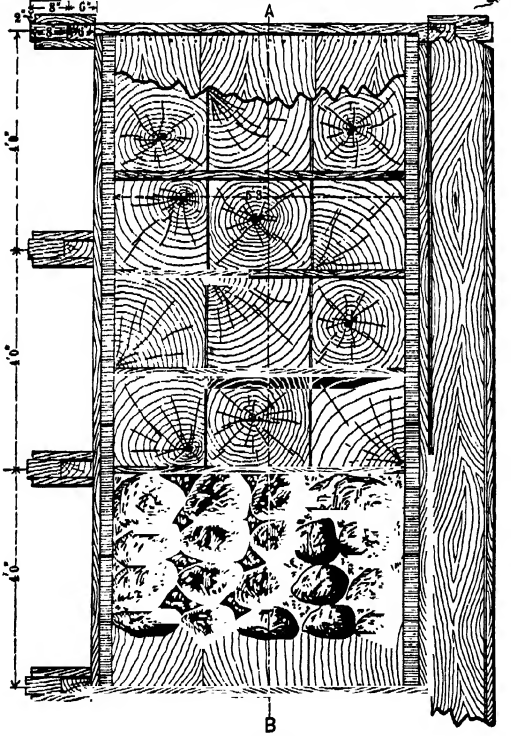


Fig. 62.

Figs. 62, 63, and 64. Tunnel Sluice Box at North Bloomfield.

stone riffles are used the bottom of the sluice is lined with rough plank.

The top sluice on one side is for carrying sipage water when the blocks are being set. It is 13 inches wide and 14 inches deep, and is made of 1½-inch plank.

Bed-Rock Claim Sluice Boxes.—At the Bed-Rock Claim, Nevada County, the tunnel sluice boxes are 14 feet long, 5 feet wide, and 32 inches deep. The details of a box are as follows:

4 Sills	4 inches ×	6 inches ×	7 feet.	
8 Posts	4 "	× 6 "	× 3 "	2 inches.
16 Braces	1½ "	× 4 "	× 2 "	
2 Top rails	2 "	× 7 "	× 14 "	
3 Bottom planks	1½ "	× 20 "	× 14 "	
2 Tongues	1 "	× ½ "	× 14 "	
2 Side planks	1½ "	× 20 "	× 14 "	
2 " "	$1\frac{1}{12}$ "	× 12 "	× 14 "	
9 Riffle strips	1¼ "	× 3 "	× 5 "	

28 Lineal feet side lining (blocks 3 inches × 20 inches).
28 Lineal feet bracing to hold down sluice, 4 inches × 6 inches.
27 Blocks, 17 inches square, 13 inches deep.

In the construction of a box there are used:

Lumber and side lining, 650 feet, at $20	$13 00
Blocks, 704 " " $14	9 86
Nails, 20 lbs. " 5 cents	1 00
Labor at $2 50 to $3 per day	7 00
Cost per box	$30 86

La Grange Sluice Boxes.—At the La Grange Mine, Tuolumne County, a sluice box 4 feet wide, 32 inches deep, and 16 feet long is built as follows:

4 Sills	4 inches ×	6 inches ×	7 feet.	
2 End posts	4 "	× 6 "	× 3 "	2 inches.
6 Intermediate posts	4 "	× 4 "	× 3 "	2 "
16 Braces	1 "	× 6 "	× 3 "	
2 Bottom planks	1½ "	× 24 "	× 16 "	
4 Side planks	1½ "	× 16 "	× 16 "	
2 Side linings	1½ "	× 8 "	× 16 "	
2 Top rails	1½ "	× 8 "	× 16 "	
12 Riffle bars	1¾ "	× 2 "	× 4 "	

Aggregating 420 feet of lumber.
36 Blocks, 14 inches square and 8 inches deep.

To each box 15 pounds of nails are used—viz.:

12	Nails,	10*d.*,	side lining to sides.
160	"	12*d.*,	braces to posts and sills.
40	"	20*d.*,	posts to sills.
76	"	"	sides to bottoms.
36	"	"	blocks to riffle bars.
32	"	"	bottom sides to posts.
64	"	"	top sides " "
50	"	30*d.*,	bottoms to sills.
50	"	"	top rails to posts and sides.

The cost per box was:

420 feet lumber, at 3 cents per foot.........	$12 60
36 Blocks, " 35 "	12 60
15 lbs. Nails, " 4¼ "	64
Labor at $1 to $2 50 per day..............	2 50
Total........................ ..	$28 34

Riffles.—The use of riffles dates back to the earliest days of gold-washing. Blankets, hides with the hair turned uppermost, and grass sods were employed by the primitive South American miners, and also steps cut in the bare bed-rock. In California every variety has been tried, but blocks and rocks are now generally used.

The character of the riffle employed is dependent upon the length of the sluice, while the length of the sluice, in turn, depends upon the hardness of the gravel, and more especially upon the character of the gold—scale gold, with large amounts of black sand and fine sulphurets, escaping all riffles for long distances.

Block Riffles.—Block riffles are square wooden blocks 8 to 13 inches deep, set on end in rows across the sluice, with each row separated by a space of 1 to 1½ inches. They are kept in position by riffle strips, 1¼ inches thick by 2 or 3 inches wide, held crosswise on the bottom, between the rows, by the side lining, and secured to the blocks by means of headless nails. Block riffles are also set and firmly held in position by means of soft pine wedges driven between the blocks and the sides of the

sluice. When wedges are used the sides of the blocks should be square where they adjoin one another. A side lining is required in all sluices. In cement claims blocks 3 inches thick, and covering 18 to 20 inches (in depth) of the side, are used for side lining.

Advantage of Block Riffles.—The advantages afforded by blocks, which should always be used at the heads of sluices, are:

1st. The cross riffle which they make is not excelled by any other form.

2d. Their cheapness under ordinary conditions of timber supply.

3d. The convenience of cleaning up, which can be quickly and cheaply done.

This last circumstance is of especial importance, because it is often desirable to collect the gold at frequent intervals, as it is injudicious to expose amalgam collected in the riffles to wear by the gravel running over it for long periods.

Experience shows square block riffles to be the best for saving gold. The objection to their use is the cost of wear and tear. Rocks are the most economical substitute, but sluices set with them require steeper grades and more water.

Life of Blocks.—The life of a block depends on the quality of the wood, the grade, the character and quantity of the gravel, and the amount of water. The larger the amount of water (on the same grade) in proportion to that of gravel, the less the wear of the blocks. The quality of the wood varies greatly in different localities. The best and most desirable timber comes from the higher sierra. Wood which is long-grained and "brooms up" makes the best riffle. Hard timber which wears smooth (as oak) is not desirable. Nut pine is the best, but it is difficult to obtain. Pitch pine answers all requirements. As a rule the price of lumber governs the selection.

In the 6-foot sluices of the North Bloomfield Mine, with a 4½ per cent. grade, the blocks, which are 13 inches deep and 20 inches square, last for a run of 175,000 to 200,000 inches of water. At the Manzanita and French Corral mines the sluices are 5 feet wide and have a grade of 4¾ per cent. The blocks, of the same size as the last, but of rather poorer timber, have a life generally of 125,-000 to 150,000, sometimes of only 100,000, inches of water.

At La Grange, in 4-foot sluices on 2 per cent. grades, the blocks, 14 inches square and 8 inches deep, are estimated to last an average of six months, during which time about 100,000 to 110,000 inches of water are run over them.

After each run the blocks are turned and replaced in the sluice, if not worn down too much. A block reduced to 5, or at most 4, inches in depth is considered unserviceable. In repaving with old blocks the edge worn down the most is placed up-stream. As the blocks do not fill the whole width of the sluice, the alternate rows are fitted so as to break joints.

Rock Riffles.—In many localities stones instead of blocks are used for riffles, and where heavy cement is washed the former are considered preferable on account of their cheapness. At Smartsville they have been found to serve fully as well as blocks, and are claimed to be cheaper. It must be stated, however, that they are more costly to handle, as longer time is required to clean up and repave the sluices.

The stone riffles as quarried are of irregular size and shape, and are set in the sluice with a slight tilt downstream. The hard rock used at the Manzanita Mine, Sweetland, Nevada County, costs about $10 per box (14 feet long and 5 feet wide).

Blocks and Rocks.—A system of riffles consisting of a row of blocks alternating with an equal section of rocks has been found to work successfully. This arrangement of the sluices reduces materially the wear and tear

of the blocks, and has given excellent results. The block-and-rock riffles are not desirable for those sluices which have to be frequently cleaned up.

Longitudinal Riffles.—In some districts longitudinal riffles, made of scantling placed lengthwise in the sluice, are preferred. At the Paragon Mine, Placer County, where the banks contain many large boulders, the riffles are made of 6-inch scantling 1½ inches wide, 8 feet long, separated by blocks 1½ inches wide; and an iron bar, 1½ inches wide and 1 inch deep and 8 feet long, is fastened on top of each scantling. The grade of the Paragon sluices is 18 inches per 12-foot box, and the width of the sluice is 44 inches.

Bed-Rock Riffles.—In the tunnel of the North Bloomfield Mine the lower 6,000 feet are run without a sluice, the bare bed-rock being used. Up to 1877, 7,000,000 cubic yards were washed through the tunnel, and an examination at that period showed that the tunnel had been deepened about 16 inches, and, though the sides were worn smooth, troughs and holes were found hollowed out at different places. A partial examination of the tunnel made in the fall of 1882 showed the existence of many holes in the bottom, in some instances 6 feet deep, but the wear on the entire line may be said to average 3 feet, about 22,000,000 cubic yards of gravel having passed through it.

On long sluice lines it is common to use several kinds of riffles.

Branch Sluices.—Where the topography of the country compels the building of branch sluices, or a light dump requires the frequent change of the tailings discharge, great care must be taken in constructing the connections with the main sluice; otherwise, in "turning into" and "turning out" from a sluice, the gravel forms a bar either above or below the junction.

Where heavy grades can be obtained no difficulty is encountered; but where the inclination is slight, good

judgment must be exercised in fixing the grades and curves, in order to make the sluices run uniformly and draw the material.

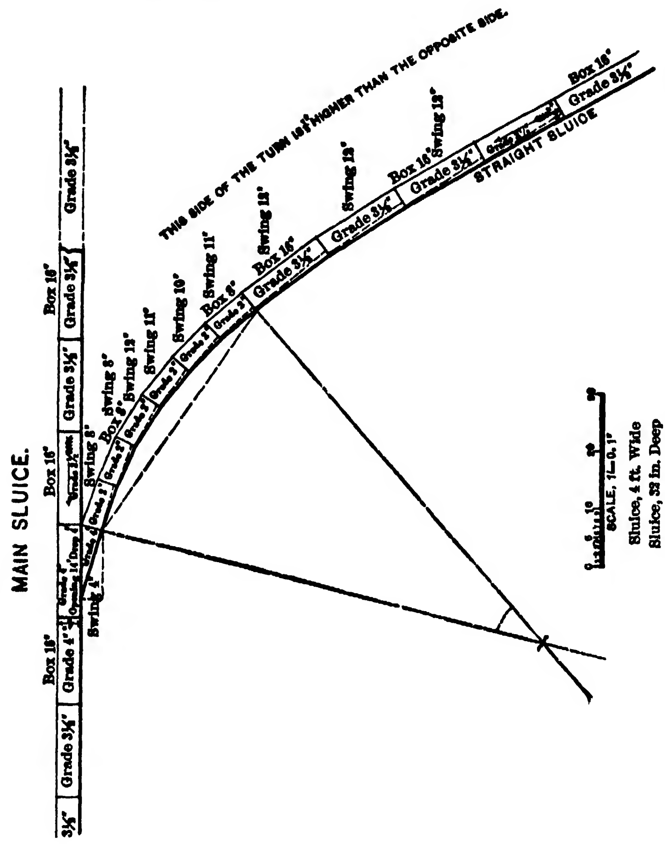


FIG. 65. TURN-IN SLUICE AT HEAD OF TUNNEL, DELANEY CLAIM, PATRICKSVILLE.

Turn-in Sluice.—The diagram shows a "turn-in" sluice adopted, after many experiments, at the Delaney Claim, Patricksville. It was set with what is perhaps the sharpest curve that can be given, for successful work, to a sluice 4 feet wide and 32 inches deep, on a 3½-inch grade to 16 feet.

The amount of water used was from 1,000 to 1,400

twenty-four-hour inches. The grade was light, and dump for the tailings could be obtained only by means of direct connection made with the Patricksville main sluice line.

With any decrease of the radius the sluice would not run uniformly, but would deposit tailings. The smallest radius of the curve having been ascertained by experiment, the next question that presented itself was, Would the main sluice carry the tailings discharged into it? As the main sluice was straight, and the general fall of the ground slight, an attempt was made to economize grade and run this sluice, with its original grade of 3 inches to 16 feet, below the junction, but the experiment was unsuccessful. The main sluice was then taken up, and a 1½-inch drop was given from the turn-in sluice at the junction, and the first two boxes from this point were set on a grade of 4 inches to 16 feet, while the remaining boxes had a 3½-inch grade to 16 feet. This improved matters, but material still accumulated in the main sluice at the junction and in the one box below. The turn-in sluice was then given a drop of 4 inches at the junction, and the discharge opening was increased from 11 to 14 feet; the sluices then ran uniformly.

The outer curve of the sluice was set a half-inch higher than the inner side. The boxes forming the curve were made in lengths of 8 feet each, and a grade of 2 inches given to each length. The head of the sluice was straight, as well as the lower end below the junction.

Turn-out Sluice.—The "turn-out" sluice is generally used when the dump-room is very limited. It is more difficult to operate on a light grade than a "turn-in" sluice.

At the La Grange Company's mines the grades varied from 2¾ inches to 4 inches per 16 feet, and the dump-room was very limited, necessitating many turn-out sluices and frequent sharp curves. As the dumps filled up the sluices were extended, and every available space was utilized which could be reached with a branch sluice.

The opening at the points of divergence was originally made 14 feet wide, and a drop of $1\frac{1}{2}$ inches given from the main sluice to the turn-out sluice, which latter was set on a "swing" of 4 inches to 16 feet.

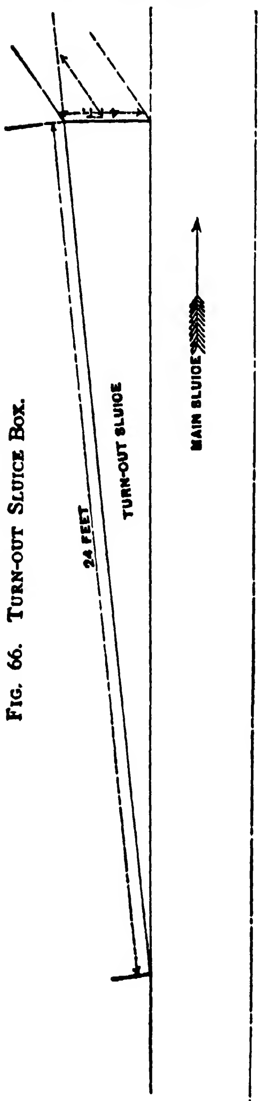


FIG. 66. TURN-OUT SLUICE BOX.

The sluices thus constructed were found to run satisfactorily; but on increasing the swing (as became necessary) to 5 inches the boxes on either side of the junction choked, only partially discharging the material, which difficulty could not be obviated by increasing the grade. On increasing the width of the discharge opening from the main sluice, which was gradually widened from 14 feet up to 24 feet, the sluices ran uninterruptedly and no further difficulty was experienced.

The first box bottom was cut in the form shown in Fig. 66—that is, from a point to full width; the succeeding half-box, of 8 feet, was high on the outside, set with a slight increase in grade, and given a 4-inch swing. All the other boxes were set with a swing of 8 inches to the box, and on the grade of the main sluice for a total distance of 200 feet, after which it was found necessary to straighten the sluice for some distance to give the water opportunity to regain its velocity. These experiments showed that in a 200-foot swing on a 2 per cent.

grade this was the greatest possible curve that could be successfully given to a 4-foot sluice. The curve, however, could be increased in proportion to the grade.

At the turn-in and turn-out it is necessary to place a board diagonally across the main sluice. This concentrates the discharge and prevents the forming of bars.

Undercurrents.—In order to relieve the sluices of the finer material, and thereby aid in saving the gold, undercurrents are introduced into the sluice line. These may be described as broad sluices set on a heavy grade at the side of and below the main sluice.

Where a drop off can be made in the main line, parallel steel or iron bars, 1 by 4 inches, with intervals of 1 inch between them, and 10 to 20 in number, according to the size of the undercurrent, are placed edgewise across the sluice. A set of such bars is called a "grizzly." It is set 1 inch below the sluice pavement, which is raised as it wears down. If too low, the grizzly clogs with gravel.

The coarse material passes over the grizzly, and, if the topography permits, is dropped and picked up again in sluices at a lower level.

The finer gravel drops through the bars into a box about 20 inches deep, lined with blocks and set at right angles to the main line. This box carries the material to the chute at the upper end of the undercurrent.

This chute is lined with cobbles and provided with "dividers" of wood to evenly distribute the material over the surface of the undercurrent. It has a 2 or 3 per cent. grade and gradually narrows towards the lower end.

The undercurrent proper is a shallow wooden box, 20 to 50 feet wide, 40 to 50 feet long, with sides about 16 inches high. It should have, if possible, 8 to 10 times the width of the main sluice. The bottom is made of 1½-inch plank tongued and grooved, and set on a grade of 8 to 10 per cent., according to the smoothness of the riffles employed. It is paved with cobbles, wooden rails shod with strap iron, or small wooden blocks. With the smooth

rails a grade of 12 inches in 12 feet is sufficient; but with blocks the grade should be increased to 14 inches in 12 feet, and with cobbles to 16 inches in 12 feet.

The gravel escaping from the undercurrent is led back to the main sluice.

The chief cost of maintenance is occasioned, not by the undercurrent itself, but by the repairs on the main sluice and grizzly, caused by the introduction of the latter into the sluice line. The running expense of a wide undercurrent is no more than that of a narrow one, excepting in the slight matter of pavement and cleaning up.

At French Corral, with a tail sluice 5 feet wide, the yield of the first undercurrent, which was 20 feet wide, was 20 per cent. of the yield of all the undercurrents. An addition of 10 feet to the width increased its yield to 27 per cent. of the total, and the grizzly in the main sluice was not changed.

TABLE XXV.

Lengths and Grades of the principal Tunnels in the Mining District of Smartsville, Yuba County, California.

Name of Tunnel.	Locality.	Length of Tunnel.	Average Grade of Tunnel.	
			Inches per Sluice Box.	Feet per 100.
		Feet.		
Babb..........	Timbuctoo......	1,200	5½ in. to 12 ft.	3.80
Pactolus.......	"	1,700	6 " to 12 "	4.16
Rose's Bar......	"	1,600	6 " to 12 "	4.16
Blue Gravel....	Sucker Flat.....	1,100	6½ " to 12 "	4.50
Pittsburg.......	" "	900	6 " to 12 "	4.16
Blue Point.....	" "	2,250	6 " to 12 "	4.16
Enterprise......	" "	1,200	6 " to 12 "	4.16
Deer Creek.....	Mooney's Flat...	2,200	5 " to 12 "	3.40

TABLE XXVII.

Cost of Construction of the French Corral Tunnel and Sluices.

Disbursements.	1,378 feet of Tunnel.* Total.		Per Foot.	Per Cent.	286 feet of Tunnel.† Total.		Per Foot.	Per Cent.	92 feet of Shaft; 118 feet of Tunnel;‡ total, 210 feet. Total.		Per Foot.	Per Cent.	Sluices and Undercurrents.§ Total.		Per Cent.
Labor		$16,702 25	$12 12	45.8		$6,949 41	$24 30	59.8		$6,149 87	$29 29	73.6		$8,813 09	44.7
Material:															
Explosives	$9,485 95		....	...	$1,057 38		...	....	$777 10		....	....	$100 00		....
Lumber	440 27		....	....	114 37		....	....	206 03		....	....	9,214 33		....
Lights	169 75		....	....	195 88		....	...	152 83		....	....	......		....
Tools, oil, etc.	938 25		....	....	33 62		....	....	91 65		...	....	50 00		....
Steel and iron	842 66		....	....	99 40		....	....	191 70		....	...	468 75		....
Charcoal	437 07		....	....	165 00		....	....	124 43		....	....	40 00		....
Nails	109 14		....	....	......		....	....	......		....	....	525 00		....
Hauling	43 75		....	....	7 25		....	....	6 37		....	....	......		....
Total		12,466 84	9 05	34.2		1,672 90	5 85	14.4		1,550 11	7 38	18 6		10,398 08	52.8
Machinery and Power:															
Water for power and air	3,053 00		....	....	2,571 40		....	....	226 67		....	....	500 00		....
Hoisting machinery, etc.	980 09		....	....	105 89		....	....	90 30		....	...	......		....
Drilling machinery, lathe, etc.	1,700 00		....	....	......		....	. ..	......		....	....	......		....
Total		5,733 09	4 16	15.8		2,677 29	9 36	23.0		316 97	1 51	3.8		500 00	2.5
General:															
Sup't and office expenses	1,507 65		....	....	324 42		....	....	324 42		....	....	......		....
Legal	37 52		....	....	8 03		....	....	8 03		....	....	......		....
Total		1,545 17	1 12	4.2		332 45	1 16	2.8		332 45	1 53	4.0		......	....
Grand Total		$36,447 35	$26 45	100.0		$11,632 05	$40 67	100.0		$8,349 40	$39 76	100.0		$19,711 17	100.0

REMARKS.—* These 1,378 feet of tunnel comprise 168 feet below shaft No. 1, 150 feet below and 160 feet above shaft No 2, all driven by Ingersoll drills actuated by air compressed by water-power. The material for 150 feet was hoisted through shaft No. 1.

† This was worked through shaft No. 1.

‡ This was worked through shaft No. 2, and was all hand-work.

§ This includes 3,700 feet of sluice 5 feet wide, 9 undercurrents, and 4 "secondary" sluices.

The cost of opening the tunnel (1,287½ feet) and shafts at the French Corra Mine from November 1, 1872, to November 30, 1876, aggregated as follows: Labor, etc., $94,241 46; machinery and power, $29,328 15; supplies and material, $32,128 28; freight, $1,167 80; land and taxes, $399 04; total, $157,265 23. French Corral sluices, $19,711 17.

The size of the tunnel was intended to be 7′×7′, but subsequently it was increased to 8′×8′. The whole length of the tunnel is 5048.59 feet. The approximate cost of the last 1,500 feet can be stated to be $25 per foot.

TABLE XXVI.

*Lengths, Grades, and Cost of important Tunnels in Nevada County.**

Name of Mine or Tunnel.	Locality.	Length of Tunnel.	Average Grade. Per Sluice Box.	Per Cent.	Cost.
		Feet.			
Boston	Woolsey's Flat	1,600	10½ in. to 12 ft.	7¼	$40,000
North Bloomfield	Humbug Cañon	9,200†	6½ " to 12 "	4½	528,000†‡
Farrell	Columbia Hill	2,200	6 " to 14 "	3½	....
English	Badger Hill	2,000†	12 " to 14 "	7	....
American	Below San Juan	5,000†	10½ " to 14 "	6¼	160,000†
Manzanita	Sweetland	3,500†	7 " to 14 "	4⅙	92,000†
Sweetland Creek	"	2,200	8 " to 14 "	4¾	90,000
Bed-rock	Below Sweetland	4,400†	9 " to 14 "	5¼	75,000†
French Corral	French Corral	5,048†	8 " to 14 "	4¾	190,000†

* Originally extracted from J. D. Hague's Report on the Eureka Lake and Yuba Canal Co.
† All figures marked thus are corrections of the original. ‡ With eight auxiliary shafts.

TABLE XXVIII.

Cost of Construction of Tunnel and Sluices at Manzanita Mine.

Expenses.	Manzanita Tunnel.		Manzanita Shaft.		Manzanita Tail Sluice.		Total.
Labor, etc.:							
Sup't and Accountant	$1,400 20		$1,400 20		......		
Office expenses	70 24		70 24		......		
Travel of Sup't	73 69		73 68		......		
Hauling	119 11		167 66		$4 00		
Miners and laborers	19,459 24		11,777 99		8,983 67		
		$21,122 48		$13,489 77		$8,987 67	
Supplies and Materials:							
Explosives	1,997 22		809 55		276 35		
Lumber	588 22		114 35		6,134 67		
Lights	345 55		92 25		......		
Tools and miscellaneous supplies	211 27		407 92		70 00		
Steel	239 60		79 61		10 00		
Charcoal	603 65		230 02		20 00		
Iron	50 00		......		265 31		
Nails	......		......		614 51		
Blocks for sluice	......		......		1,098 43		
		4,035 51		1,733 70		8,489 27	
Machinery:							
Pipes, shafting, etc.	203 79		163 79		......		
Water-power	65 00		772 43*		......		
		268 79		936 22			
Legal Expenses:							
Counsel fees, etc.	22 73		1,267 61		......		
Taxes:							
Taxes before completion	150 00		150 00		......		
		172 73		1,417 61			
		$25,599 51		$17,577 30		$17,476 94	$60,653 75

* 10,905 ten-hour inches.

NOTE.—The item $25,599 51 shows the cost of driving the Manzanita Tunnel from a point

756 feet from its mouth to a point of junction with the heading from the shaft, a distance of 851 feet; cost $30 08 per linear foot. The amount $17,557 30 is the cost of sinking the shaft 123 feet and driving a heading from it 93 feet to connect with the lower (tunnel) heading; cost $81 38 per linear foot. The amount for tunnel and shaft ($43,176 81) is the cost of the entire tunnel to the Milton Company. Previous, however, to the formation of this company the tunnel had been driven in 756 feet at a cost of about $25 per foot, or, say, $19,000; adding this $19,000 to the $43,176 81 expended by the Milton Company gives $62,176 81 as the total cost of tunnel and shaft, or nearly $35 per linear foot. The third item of $17,476 94 represents the cost of construction of a tail sluice, 4,774 feet long, from the mouth of the tunnel to the Yuba River, 7 large undercurrents of the most approved pattern, and the labor of putting a flume in the tunnel 1,700 feet long. The three accounts summing $60,653 75 + $19,000 (amount expended on tunnel before organization of the company), say $80,000, represents the entire cost of tunnel and sluices ready for washing. Size of tunnel, 8′ × 8′.

CHAPTER XV.

TAILINGS AND DUMP.

Tailings.—The refuse material thrown aside in quartz, drift, hydraulic, or other mines, after the extraction of the precious metal, is called "tailings." The tailings from hydraulic mines are called "débris" also.

The number of cubic yards of débris from the various gravel mines discharged in 1880–1 into the streams and valleys of California, between Chico Creek on the north and the Merced River on the south, has been estimated at about 46,000,000. To this amount, according to Professor Price, there should be added 1,000,000 cubic yards from the tailings from the working of 1,500,000 tons of quartz by 12,546 stamps in mills.

Composition of Tailings.—The tailings from mills consist of pulverized quartz particles. The refuse from gravel-washing is of all forms and dimensions, and is composed of the most diversified materials. The light particles of soil, loam, and sand are easily carried forward by running water, while the rocks and boulders, though readily transported through sluices, lodge and distribute themselves, when discharged therefrom, in the creeks and streams in accordance with their size, shape, and specific gravity, and for their further removal the agencies of time and flood are necessary.

Cemented material and pipe-clay are more or less disintegrated and ground down in the process of sluicing. When subjected to the action of running water further pulverization and disintegration ensue, the actual amount of which is unknown.

Wear in Running Water.—The wearing down of

solid cobbles and boulders by running water after lodgment in the beds of large streams, at a distance from the mine, is not great. When these materials are carried further forward by floods or torrents they move along the bottom until they find permanent lodgment, consequent upon a decrease in the grade of the bed of the stream or from some other cause. In water the weight of rocks is materially lessened, and the friction which would be due to their weight is correspondingly decreased.

The constant collision and rubbing of the harder rocks against each other smooths and polishes them, somewhat changes their form and lessens their surface, and, to a certain extent, reduces them to fine powder but not to sand. Experiments made to ascertain the wear due to erosion of solid materials transported by rivers or streams tend to establish the fact that no perceptible deposit can be attributed to such cause, as the sediment from such wear is found to be a very fine powder, which immediately passes off in suspension.

The distribution of gravels along the course of any stream will be found to be in accordance with their size, form and specific gravity, and distance from the source. Thus the material composing the bed of a stream, which may at its source consist entirely of large boulders and cobbles, will become finer and finer through the successive stages of gravel, pebbles, and sand, until it is finally discharged as muddy water into the ocean.

Effects of Hydraulic Débris.—The working of hydraulic mines in California has here and there given rise to disputes with farmers. These disputes have, unfortunately, been carried into the domain of local politics, and thereby not only brought into undue prominence, but also exaggerated, and an equitable settlement prevented. Meantime manipulators have taken advantage of the situation to the detriment of both the farming and the mining interests.

The navigable waters affected by the mines are the bays of Suisun and San Pablo and the Sacramento, San Joaquin, and Feather rivers. The smaller and non-navigable streams which receive more or less of the sands are (besides the Trinity and Klamath rivers, where so little washing is done that they need not be considered): the American (tributary of the Sacramento) in the north; and the Merced, the Tuolumne, the Stanislaus, the Calaveras, the Mokelumne, and the Cosumnes (tributaries of the San Joaquin) in the south. The quantity of débris which has been washed into these streams is unknown, and data based on reconstructed topography in the mining regions are, from the nature of the case, simply guesses. The only available method of estimating with any approach to accuracy the amounts of material mined seems to be that of taking the water used and averaging the duties of the inch, as surveys of the washings are kept up only in exceptional cases.

The inch differs as much as 20 per cent., the nature of the ground mined continually changes, and the character of the sluices varies not only in every district but in almost every claim. These estimates, therefore, must be considered as the mean of many conjectures. It can be safely stated that only in a few instances do any of the ditches discharge the quantity of water which they are rated to deliver according to official statements or in the assessors' returns, from which sources chiefly the cubic yards mined have been estimated.

The following tables, XXIX. and XXX., are based on this method. Table XXIX. is from William Hammond Hall, State Engineer, Report of 1880, part iii. p. 24. Table XXX. is from Lieutenant-Colonel G. H. Mendell's Report upon Mining Débris in California Rivers, 1882, p. 15:

	TABLE XXIX. Season 1878–79. Cubic Yards.	TABLE XXX. Season 1879–80. Cubic Yards.
Table Mountain Creek	3,556,000	2,919,375
Butte Creek	......	84,000
Feather River	12,687,500	4,407,770
Yuba River	22,326,500	19,103,598
Bear River	5,550,000	3,351,246
Dry Creek, No. 2	680,000	132,687
American River	8,604,000	8,615,250
Total	53,404,000*	38,613,926†

In the region south of the American River Mendell's Report shows the discharge of tailings to be 7,414,465 cubic yards.

The differences in the above tabulated estimates, which were undoubtedly prepared with care, show how difficult it is to arrive at exact data. In view of the fact that the details on which the calculations are made are not given, it is impossible to criticise with fairness. It would appear that the duty of the inch is rather too large.‡

By far the greater part of the material washed remains comparatively near the ends of the sluices in the cañons until removed by heavy freshets. "In the Polar Star and Southern Cross mines, at Dutch Flat, I have estimated that nearly 50 per cent. of the material mined is of a character which need never be carried a mile below the dumps; it is of heavy rock and cobble-stones, and probably not over 45 per cent. of the whole need ever become sandy and sedimentary in character if reservoired before being transported very far; so that all but about 15 per cent. could be held readily behind dams and other obstructions in the cañons." §

* The State Engineer's estimate of quantities washed is based upon the returns of the amount of water used, made by mining superintendents or secretaries, on blank forms furnished from the State Engineer's office.

† Colonel Mendell's estimate is based upon returns of water used in mining, made by the county assessors to the State Engineer, as provided by law.

‡ The average duty of the inch for the region draining into the Sacramento Valley is (according to the tables) 3.6 cubic yards, and for the region south of the American River 2.2 cubic yards. The latter is certainly, and the former probably, too great.

§ Report of the State Engineer, 1880, p. 23.

The coarse detritus which gets into the streams and is subjected to the action of floods is moved along when the grades are over 40 feet to the mile, and is deposited mostly when the grade is lessened to between 30 and 20 feet. "The sands predominate greatly" when the grade is reduced to 10 feet and less.*

The finest and lightest material is held in suspension until the velocity of the water carrying it is greatly reduced. The amount of material suspended in the California rivers has been estimated from tests made of these waters, but these tests have not been continued for a sufficient length of time to afford any reliable results.

The deposition of this material on lands overflowed during high water was one of the original causes of the disputes mentioned above.

Up to the year 1880, the total area in the Sacramento Basin thus affected is estimated by the State Engineer at 43,546 acres, a large portion of which was of little value and had always been subject to overflow.

The catchment area on the east side of the Sacramento Valley is very large, and the descent from the high sierra to the valley is very abrupt and precipitous. During the stormy seasons immense quantities of water, caused by rainfall and melting snows, are rapidly discharged into the lowlands, where the river channels, having but small areas † and light grades, are unable to carry them off, and floods invariably follow.

The reservoirs which have been constructed by the hydraulic mining companies in the mountains partially mitigate the evils arising from this source.

THE DUMP.

It is impossible to lay too much stress on the importance of the dump, as without it hydraulic mining could not be carried on. Where thousands of cubic yards of

* Report of Lieutenant-Colonel Mendell, pp 33 and 34.
† See vol. ii. p. 7 Trans. Tech. Soc. of the Pacific Coast.

alluvions are being washed daily from their position, places must be provided at lower elevations where the gravel can be deposited. A much larger superficial area is usually required for this than was primarily occupied by the material removed, as the dumps seldom have the depths of the original deposits.

Working on different Bed-rock Levels with same Dump.—It sometimes happens in adjacent claims with small dump-room that the bed-rock of one is lower than the other. Where this occurs the claim with the highest bed-rock should be the last run off.

An illustration of this was afforded at Patricksville, in Stanislaus County, where three claims were worked, one tailing over the other. During the years 1876 and 1877 the lowest claim, called the "Chesnau," was closed each fall, the dump giving out, while the upper ones continued work. With the return of spring freshets the cañon was cleared of the débris, and washing was regularly resumed in the Chesnau, continuing as long as the dump lasted. The highest claim was closed while the Chesnau was working, to avoid the too rapid filling-up of the creek. If both upper claims had been worked at the same time the Chesnau would soon have been closed.

Tailing into Streams.—The want of dump is remedied only in exceptional cases by discharging into a current or mountain torrent. This occurs where the gold placers are on the borders of large, rapid, and well confined streams; but in the mountains, where the gold-bearing deposits are found, the rivers are narrow and shallow, only running water in quantity during the winter and early spring.

Experience at La Grange, on the Tuolumne.—Some of the annoyances and difficulties arising from tailing into a stream can be seen on the Tuolumne River below La Grange. The river, a large mountain stream which runs over a hard slate bottom, has for 17 miles above the town a fall approximating 18 feet to the mile,

and is well confined by abrupt banks. Opposite the old French Hill dump the river is 500 feet wide, and at La Grange, from which place to its mouth the grade is only a few feet to the mile, its width is 525 feet. Three hundred yards below the town, opposite the Light claim, it widens to 750 feet. Down the stream from this point the hills recede for the succeeding three or four miles, but subsequently form prominent banks to the river. During high water, opposite the Light claim, at its greatest width, its average depth was 10 feet, the centre of the channel being 14 feet deep. When the La Grange Company commenced work, in 1872, the bottom of the channel was a few feet deeper.

The Light claim was worked in 1873, and up to June 23, 1874, had discharged 720,086 cubic yards of gravel into the stream. During the same period 975,064 cubic yards were dumped into the river from the Kelly and French Hill properties. The results at the expiration of 21 months were, that the channel opposite the Light claim was filled up, the sluices were run out of grade, the river bed was shoaled on all sides, the water of a formerly rapid stream straggled over the accumulated débris with a barely perceptible motion, and it is hardly necessary to add that the claim was closed.

The spring freshets of 1875–76 were unusually severe, clearing the river at the claim for its entire width and leaving a dump of over 11 feet along its west bank. In the spring work was resumed, and 48,280 cubic yards were moved in the Light claim and 212,346 cubic yards from French Hill, which was a quarter of a mile upstream. By September the river was filled up nearly its entire width to the height of the sluices, and the water was confined to a strip 30 feet wide, discharging 1 foot deep over a bar.

Exceptional Cases.—Where a small amount of tailings is discharged into narrow and steep cañons, winter rains and spring freshets suffice to clean them out; but

where the quantity is large, in spite of the water the ravines fill up gradually, and hydraulic mining in these localities ultimately ceases. It occasionally happens that the want of dump-room is obviated by a tunnel, by means of which the tailings are conveyed into large and precipitous ravines, there to await the action of time and water for their further removal.

CHAPTER XVI.

WASHING, OR HYDRAULICKING.

Charging the Sluices.—The tunnel and sluices having been completed, water is turned into the pipes and washing commences. The sluices are run half a day in order to pack them. The water is then shut off and a charge of quicksilver is put into the upper 200 or 300 feet of sluices, a small quantity being distributed along the entire line except the last 400 feet. In a 6-foot sluice the first charge will be about 3 flasks. The undercurrents are charged at the same time and a little quicksilver put into the tail sluice. Quicksilver is added daily during the run, in gradually lessening quantities, the object being to keep the mercury uncovered and clean at the top of the riffles; and therefore the charge is regulated by the amount exposed to view. At the North Bloomfield Mine, where the main sluice is cleaned up nearly every 12 days, the amount of quicksilver used in a run varies from 14 to 18 flasks. A 24-foot undercurrent will require a charge of from 80 to 88 pounds of quicksilver.

In charging the riffles all splashing of the quicksilver should be avoided. When it is sprinkled into the sluice (a practice to be condemned) it divides itself into minute particles, the bulk of which is easily carried off by the swift stream, while the lighter portions will float even in the clear water. The buoyancy of these small particles is very considerable.

Top water from mining sluices often yields minute globules of quicksilver, and float quicksilver containing gold particles (microscopic) has been taken from the surface of the water twenty miles from where the amalgam

entered the stream. In one case floating amalgam was observed on the North Fork of the Yuba River four miles below where the tailings were dumped. A flume (conveying water to a pump) was set above the bottom of the stream, drawing direct without any dam. An examination of the flume subsequent to its removal revealed the presence of about one ounce of gold amalgam, collected at the junction of the boxes.

Commencing Work.—The first work is started near the head of the sluice and the mine opened from that point. As the banks are washed away the bed-rock cuts are driven towards the face of the work and the sluices are advanced. (For blasting see Chapter XII.)

Caving Banks.—In order to cave a bank it is customary to use two pipes which throw streams from opposite sides at an obtuse angle with one another, forming a cross-fire, against the lower part of the bank. This cross-fire was supposed to be particularly efficient, but in many cases where large quantities of water and great pressures (2,500 to 3,000 inches with heads of 350 to 450 feet) are employed better results have been claimed from utilizing water in a single stream than from its subdivision through two (or more) pipes. Any surplus water may be allowed to run over the banks, but such surplus should be avoided as far as possible and all the water utilized through the nozzles.

When washing with two pipes, and the dirt caves readily, one pipe should be employed to do the cutting while with the other the falling gravel is washed into the ground sluices.

The face of the bank should be kept square. Advantage should be taken of such corners as are left, and, under all circumstances, avoid working into what is called a "horseshoe" form. When a cut is rapidly pushed ahead and the work is not squared, the men at the pipes become encircled by high banks, washing can no longer be advantageously prosecuted, and the lives of the miners are

imperiled. The majority of accidents arising from caves have been caused by this style of work.

High Banks.—Where the banks exceed 150 feet in height it is advisable to wash the deposit in two benches. At Malakoff and Smartsville single benches have been used to the limit of 250 feet, and above this double benches.

When the man at the pipe sees that the bank is about to cave the water should be immediately turned away from the falling masses; if the cave falls upon the water in the ground cut, a rush of débris ensues, and in many instances the men at the pipe have to run for their lives. Such occurrences, arising either from carelessness or accident, cause a loss of time and frequently entail damage to the pipe and machines. Caves, when practicable, are generally made towards evening, the night shift running them off.

Light.—Locomotive reflectors or fires of pitch-wood are used to illuminate the banks during the night. In some large claims electric lights have been substituted. No doubt the latter would be more generally used were it not for the cost attendant on their introduction.

Electric Light.—The electric-light machine used in illuminating the North Bloomfield mine is of the Brush pattern and nominally of 12,000 candle-power. To run it requires four horse-power, supplied through a hurdy-gurdy wheel. The light is used in two lamps.

The machine, lamps, wire, and connections cost two thousand dollars set up. It has been in almost constant use for two and a half years, running from eight to twelve hours each night.

Its running cost per night is:

Six carbons, ½ inch by 12 inches,	$0 50
Brushes and segments,	0 12
Oil, say,	0 03
Attendance, half one man's time,	1 50
Power, 10 inches water, at 2.27 cts., say,	0 23
Total cost per night,	$2 38

The cost of the pitch-wood bonfires previously used was eight dollars per night, and these gave an illumination very inferior to that of the electric light.

The lamps are placed in the open, where they are subjected to the severest winter storms without injurious effect other than the increased consumption of carbons.

Continuous Work.—The washing should be continuous and no water be allowed to run to waste. It is therefore requisite to have several faces or openings, so that the water can be used from time to time on them whilst the cuts are being advanced and the sluices lengthened. These cuts, or "ground sluices," as they are called, are trenches made in the bed-rock towards the face of the bank washed, for the purpose of collecting the water and material and conveying them to the sluices. Sometimes these cuts are very deep, say from 60 to 70 feet, and occasionally the expense of making them forms a large item.

When a claim is running the sluices are always guarded. As a protection against theft, where claims are worked intermittently, the sluices are run full of gravel before turning off the water.

Cleaning up.—The length of "runs" is dependent upon many circumstances, but chiefly upon the wear of the pavement. Some claims are cleaned up every twenty days, others are run two or three months, whilst a few, where the water season is short, are cleaned up only every season. All pavements should be cleaned up as soon as they begin to wear in grooves. Where a large quantity of water is used, and a relatively large amount of ground washed, it is considered advisable to clean up the first 1,000 or 1,800 feet of sluices (which are paved with blocks) every two weeks. With a gang of miners this work is done expeditiously, not occupying over one half-day. The tail sluices are cleaned up only once a year. The undercurrents should be cleaned up whenever quicksilver is found

spread over their lower riffles, with tendency to discharge over their ends.

When it is decided to "clean up," the bed-rock and cuts are piped clean. No material is turned into the sluices, clear water alone being run until the sluices are free of dirt.

When thus prepared only a small head of water, such as men can conveniently work in, is turned through the sluice, and the blocks are taken out by means of crow-bars, washed to free them from amalgam, and laid at the side of the sluice. This is done in sections approximating 100 feet. Between each section one row of blocks is left in the sluice. These rows serve as riffles to prevent the gold and quicksilver from passing down the sluice. After the first section of blocks is taken up men follow the gravel and dirt as these are slowly washed down the sluices, and pick up the quicksilver and amalgam with iron scoops, with which they are put into sheet-iron buckets.

As each riffle is reached the amalgam and quicksilver are collected, the block riffles removed, and the residue is washed down to the next riffle, and so on down the entire line of sluice. When this operation is completed the water is turned off and the workmen attend to the nail-holes and cracks in the sluices, "creviceing" with silver spoons to obtain the amalgam contained in them. After this the side-lagging is overhauled and the blocks are replaced. Where the sluices are of great length the lower portions are usually lined with heavy rock, which can be used for longer periods without cleaning up.

It is customary in mines which have very long sluices, and which are run at night, to clean up during the day as long a section as can be cleaned and put in order for further work, and to resume washing at night, until the whole line is cleaned up. At the end of the water season the entire works are cleaned up and put in order for the next season's run.

Treating the Amalgam.—The quicksilver and amalgam obtained is well stirred in buckets, and the coarse sand, nails, and other foreign substances which float on the surface are skimmed off. This residue (which holds considerable amalgam) is concentrated by washing in pans or rockers, and the concentrations ground in iron mortars and treated with more quicksilver. Any base material which floats on the surface of the bath is melted by itself to a base bullion. The remainder is added to the fine amalgam. The amalgam is strained from the quicksilver through drilling, and the dry amalgam is retorted in iron retorts.

Retorting.—Where the amount of amalgam obtained is small the hand retort is used, but at large gravel-mines the cast-iron retorts are made stationary, similar to those used at gold and silver quartz mills, only that they are smaller. Where large quantities of amalgam are retorted and the furnaces when fired are left unattended, as is frequently the case, the retort, which is set immediately above the fire, becomes overheated. The weight of the metal which it contains then causes the retort to "belly," which ruins it. To overcome this difficulty the retort should be set with supports and arranged with the fire to one side, that the heat may be evenly distributed over it. Retorts thus set are found to work well in practice. (See Figs. 70, 71.)

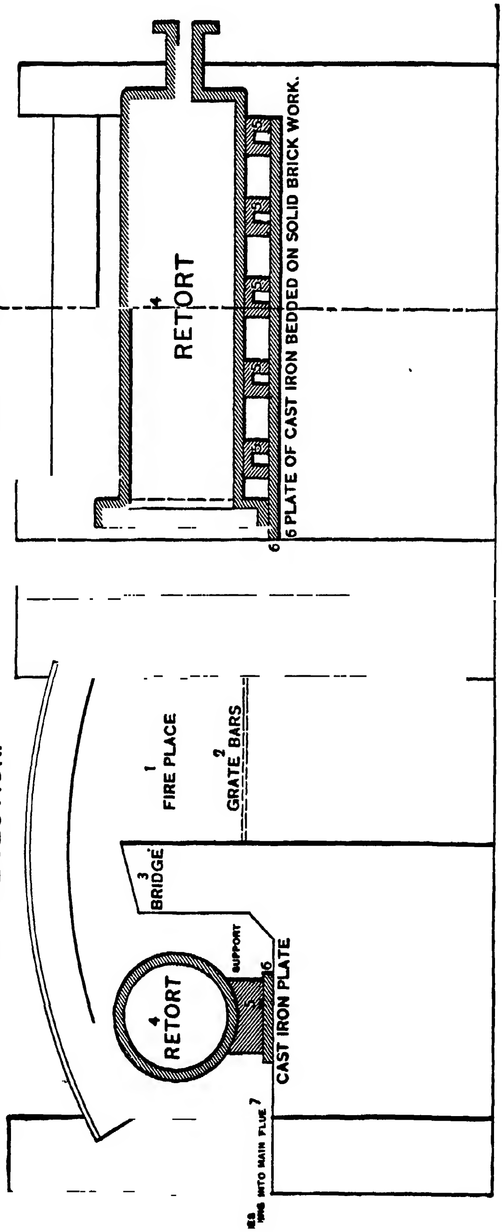
Before the amalgam is put in the retort the interior is coated with a thin wash of clay, which prevents the amalgam adhering to the iron.

The amalgam should be carefully introduced and evenly spread. The iron pipe which connects the back end of the retort with the condenser must be clear of all obstructions, and under no circumstances should the amalgam be spread so that the pipe can possibly become choked, as in that case an explosion would probably ensue.

To avoid any danger arising from this source, after the cover has been put on, luted with either clay or a

Fig. 70.
TRANSVERSE SECTION.

Fig. 71.
LONGITUDINAL SECTION.



FIGS. 70, 71. THE RETORT.

mixture of clay and wood-ashes, and securely clamped, the fire is lighted and the heat gradually raised, a dark-red heat being all that is necessary to thoroughly volatilize the quicksilver. Towards the end of the operation the heat is raised to a cherry-red color, at which it is kept until distillation ceases. The retort is allowed to gradually cool, and when cold is opened.

During the operation the condensing-coil at the back of the retort should be kept cool by a continuous supply of fresh water entering from the lower end of the box which contains it, whilst the discharge of warm water is effected above.

The retorted bullion is cut or broken in pieces and melted in a well-annealed black-lead crucible, and the gold cast into bars.

CHAPTER XVII.

THE DISTRIBUTION OF GOLD IN SLUICES.

IN cleaning up sluices the largest portion (approximating 80 per cent.) of the gold caught is found in the first 200 feet. The gross yield of the Gardner's Point claim for the season of 1874 was $63,000 for 100 days' run. Of this amount $54,000 were obtained in the first 150 feet, and $3,000 were taken from the undercurrents. The remainder was found lower down along the sluices. The first undercurrent was 790 feet distant from the head of the sluice, and yielded 50 per cent. of the total yield of the undercurrents. The second undercurrent was 78 feet distant from the first, with a drop of 40 feet between them, and it contained 33 per cent. of the gross undercurrent yield. The third undercurrent was 91 feet distant from the second, with a drop of 50 feet between them. Its yield was nearly $500.

It sometimes happens that a hundred or a hundred and fifty feet at the head of a sluice are covered with gravel during the greater part of a run. In such cases the gold is found farther down. In the North Bloomfield tunnel the upper 300 feet of the sluice are generally filled from one to five feet deep with gravel, and still this portion yields much more amalgam per linear foot than the succeeding 300 feet of sluice. The following data from the report of this company for the year ending October 31, 1876, are worthy of note, as showing the position of the gold in the sluices at "No. 8" claim, where some 700,000 inches of water were run, washing 2,919,000 cubic yards of gravel:

Sump	$1,510 00	0.80	per cent.	of	gross	yield.
Flume (1,800 ft.)	176,900 73	92.00	"	"	"	"
Tunnel below flume	7,290 00	3.75	"	"	"	"
Tail sluice (300 ft.)	1,800 00	0.95	"	"	"	"
Undercurrents	5,235 00	2.50	"	"	"	"
	$192,735 73	100.00	"	"	"	"

Mr. P. Wright, assistant engineer for water-supply, Beechworth District, Australia, in giving his experience on the subject of the distribution of gold in sluices, says: "With a sluice 12 inches wide, on an incline of one foot to 48 feet, using 600 gallons per minute, I have found 95 per cent. of the gold within three feet of where the gravel was filled into the sluice—where the gold was lying on a smooth board, and yet a powerful current failed to move it." *

Distribution in Tail Sluices.—The North Bloomfield tunnel (8,000 feet in length) has 1,800 feet of sluices, paved with blocks at its upper end; but in the succeeding 6,200 feet no sluices are used, the tailings being allowed to run on the bare bed-rock (a tough slate).

From the rock-cut at the mouth of the tunnel a sluice paved with rocks receives the tailings. From here on they are carried through sluices and cuts and distributed over undercurrents which are set on different grades, paved, in some instances, with rocks and blocks, and occasionally arranged with longitudinal riffles covered with strap iron. The grizzlies used are made of wrought iron, 1 by 4 inches in size, set on edge. The discharge from the several undercurrents is taken up by the main sluice and subsequently redischarged over the succeeding undercurrent until the lowest sluice and undercurrent finally discharge the tailings into the cañon. From December 1, 1876, to June 1, 1877, 354,000 24-hour miner's inches of water (2,230 cubic feet each), conveying the tailings, passed through the main sluice and tunnel and were discharged through the tail or lower sluice and undercurrents.

* "The Gold Fields and Mineral Districts of Victoria," R. Brough Smythe, p. 133.

The annexed sketch shows the general arrangement of the tail sluices and undercurrents, which latter were subdivided into compartments, as indicated.

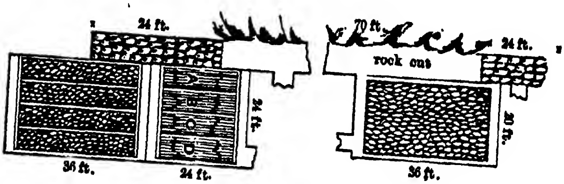


FIG. 72.

The distribution of the gold along the line of sluices and in the several undercurrents was as follows:

Tail sluices from December 1, 1876, to June 1, 1877, miner's inches of water, 24 hours each, 350,000.

150 feet at head, down to No. 1 Undercurrent, yield..........	$3,150 00
150 feet, remainder of sluice, yield..........................	350 00
Total..	$3,500 00

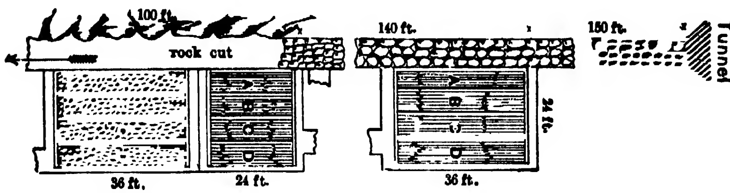
No. 1 Undercurrent—Size, 24 by 36 feet; grade, 13 inches in 12 feet; chute, 2 feet wide at opening, contracted to 10 inches; iron-rail riffles. (The undercurrents are divided into four compartments, A, B, C, and D.)

A	yielded	108⅛	ounces amalgam.	3 clean-ups.
B	"	83¾	" "	
C	"	46½	" "	
D	"	31¼	" "	
Chute	"	46¼	" "	
		316¼	" "	Value, $1,920.

No. 2 Undercurrent—Size, 24 by 24 feet; grade, 12 inches in 12 feet; chute, upper end 2½ feet, lower end 2 feet; iron-rail riffles.

A	yielded	48¾	ounces amalgam.	2 clean-ups.
B	"	36¼	" "	
C	"	20¾	" "	
D	"	23½	" "	
Chute	"	14	" "	
		143¼	" "	Value, $874.

No. 3 Undercurrent—Size, 24 by 36 feet; grade, 15 inches in 12 feet; chute, 2½ feet upper end, 2 feet lower end; rock riffles.



TAIL SLUICES AND UNDERCURRENTS.

A	yielded	50½	ounces	amalgam.	2 clean-ups.
B	"	35¼	"	"	
C	"	18½	"	"	
D	"	16	"	"	
Chute	"	8½	"	"	
		128¾	"	"	Value, $883.

No. 4 Undercurrent—Size, 20 by 36 feet; grade, 12 inches in 12 feet; rock riffles.

71¾ ounces amalgam. Value, $430.

No. 5 Undercurrent (constructed in March)—150,000 miner's inches of water; size, 24 by 24 feet; grade, 12 inches in 12 feet; chute, 2½ feet upper end, contracted to 2 feet lower end; riffles 1¼ by 4 inch lumber, covered with strap iron; nails 1 inch apart.

A	yielded	5	ounces	amalgam.	1 clean-up.
B	"	8½	"	"	
C	"	5	"	"	
D	"	6½	"	"	
		25	"	"	Value, $150.

No. 6 Undercurrent—Size, 24 by 36 feet; grade, 17 inches in 12 feet; rock riffles; chute, 2½ feet upper end, 2 feet lower end; 150,000 miner's inches of water.

A	yielded	8	ounces	amalgam.	1 clean-up.
B	"	5	"	"	
C	"	3¼	"	"	
D	"	3	"	"	
		19¼	"	"	Value, $115.

The total yield of the undercurrents and tail sluices, for the period mentioned, was $7,872, while that of the claim was $145,000.

The amalgam from the main sluice is worth from $7 50 to $8 50 per ounce Troy, whereas that of the undercurrents varies from $6 to $6 20 per ounce Troy.

The result of the undercurrents and tail-sluice clean-ups for the year 1876–7 was as follows:

	Yield.		
Cut A to B	334	ounces	amalgam.
Tail sluice B to C	1,380½	"	"
Undercurrent No. 1	648¾	"	"
" " 2	280¾	"	"
" " 3	253¾	"	"
" " 4	143¾	"	"
" " 5 } 6 months	69	"	"
" " 6 } 6 months	59½	"	"
Total in cañon	3,170	"	"

This amount (3,170 ounces) equals in value about 7 per cent. of the total yield of the mine for the fiscal year, during which period 595,500 miner's inches of water have been used, extracting $291,116 90 gold.

Comparing these final results with those of the previous year, 1875–6, the metal is found distributed throughout the sluices and undercurrents in the same relative proportions.

This fact is noteworthy, since in 1875–6 the bulk of the material moved was "top gravel," while in 1876–7 a much larger proportion of "cement gravel" was run through the sluices.

In the heavy cement at French Corral and Manzanita

a high percentage of the gross yield of the mines is found in the undercurrents.

Hydraulic mining in the "cement claims" is carried on under great difficulties. An exhibit of the workings of the sluices of a representative "cement claim" (French Corral) is here given, and the contrast thus afforded with the workings of sluices in the majority of cases is most striking and of especial interest.

The washings from the French Corral mine, after passing through the new tunnel, are successively distributed over nine undercurrents before they are finally discharged. The sizes and arrangements of these undercurrents are given in the accompanying table.

TABLE XXXI.

French Corral Mine Undercurrents, etc.

Undercurrents.					Secondaries.			Main Sluice containing Grizzly.	
From Mouth of Tunnel down.	Length over all.	Width.	Grade.*	Bottom lined with	Length.	Width.	Grade.	Length.	Width.
	Feet.	*Feet.*	*Per Cent.*		*Feet.*	*Feet.*	*Per Cent.*	*Feet.*	*Feet.*
No. 1	42	20	8	Blocks 6" wide, 4" deep..	..	..	..	..	5
" 2	42	20	8	" " "	21	12	7	42	6
" 3	42	20	8	Blocks for 14 ft..........	..	..	..	28	6
				Longitudinal rails, 28 ft..	..	..	..		
" 4	42	20	8	⅓ blocks; ⅔ rails........	..	..	..	28	6
" 5	42	20	8	" "	..	..	..	42	6
" 6	42	20	8	" "	..	..	..	28	6
" 7	42	20	8	" "	21	12	7	42	6
" 8	42	20	8	" "	..	..	..	28	6
" 9	42	20	8	" "	28	12	7	28	6

From January 14 to October 3, 1877, there were 163,263 miner's inches of water discharged over these undercurrents, and the corresponding yield of the wash-

* Grade 15 inches in 14 feet.

ings was $201,284 36 gold, 17½ per cent. of said amou being found in the undercurrents, distributed in the f lowing proportions:

TABLE XXXI A.

Yield of the Undercurrents, etc., at the French Corral Mine.

Amalgam Yield in lbs. Avoirdupois.														
	Undercurrents.									Secondaries.			Pickings from Chutes and Aprons.	Total Yield.
Nos.	1	2	3	4	5	6	7	8	9	1	2	3		
Lbs.	96	67⅛	56¾	42	31	24⅛	23¼	17	12¾	5⅝	1¾	1	9½	388⅝

As a further illustration of the distribution of gold the sluices of hydraulic claims, a classified statement given showing the workings of the sluices at the Ma zanita Mine, Sweetland, Nevada County, from Decemb 20, 1876, to October 3, 1877:

TABLE XXXII.

Date of Clean-Up.	Total amount of water used in run, 24-hour miner's inch.	Amalgam Yield in lbs. Avoirdupois.									Total.	Bullion Yield.
		Cut.	Tunnel.	Long Sluice by Section.						Undercurrents.		
				1	2	3	4	5	6			
January 4	8,626	18	48	16	..	...	.....	..	..	8	90	$7,734 87
March 17........	25,937	37	103	..	...	....	.....	..	..	30	170	15,970 53
April 23.	21,491	51	89½	..	...	....	.....	49	..	30½	220	20,238 51
June 8...........	29,187	46	78	..	...	....	83½	..	..	34¼	241¾	21,562 47
July 13..........	15,868	64	53	32	...	....	.....	..	..	8½	157½	15,401 70
August 9........	17,000	33¼	66	..	...	37¼	.....	..	..	17½	154	15,970 53
September 29....	23,400	104	124	15	109	....	28	38	64	44	526	46,307 19
From top Mine worked in March and May.	16,958	.....	.....	..	...	....	.....	..	..	.....	40¾	3,2 2 41
Total.... ..	158,494	353¼	561½	63	109	37¼	111½	87	64	172¾	1600	$146,408 21

The arrangement of the sluices here is as follows:

1st.	East cut contained, average................	40	boxes *
	West " "	28	"
2d.	Tunnel " "	120	"
3d.	Long sluice " "	300	"
4th.	Undercurrents (8 to commence, 10 at end)..	50	"
	Total..............................	538	"

The long sluice is divided into six sections, each section containing the following number of boxes:

1st	section.	29	boxes,	to second angle below tunnel.
2d	"	56	"	Pease Ravine.
3d	"	23	"	Buckeye Point.
4th	"	67	"	Armstrong Ravine.
5th	"	62	"	Quinn's.
6th	"	63	"	Lower.

The sluices in the cut are 4 feet in width, while those in the tunnel and the long sluice are 5 feet wide, all of them having a side lining of blocks 3 inches thick.

The riffles used in the cut sluices are hand-sawed blocks, 13½ by 13⅛ by 10 inches, and those in the tunnel sluices are also hand-sawed, 13½ by 13½ by 10 inches, and 17½ by 17½ by 10 inches; about half of each. In the long sluice quarried granite rocks 18 inches thick are substituted for block riffles. The grade along the line of the cut and tunnel is 7 inches in 14 feet, while that of the long sluice averages 9 inches in 14 feet, with drops of 6 inches at each angle.

The undercurrents (10 in number) are similar to those used at the French Corral mine. They are 42 feet long (the apron over which the water is spread forms a part), 20 feet wide, set on grades ranging from 10½ inches to 16 inches per box, and are paved with blocks 6 by 17 by 4 inches in size.

The three following tabulated exhibits are self-explanatory, and show in the Manzanita mine the results produced by widening the undercurrents.

* Each box 14 feet in length.

TABLE XXXIII.

Statement showing Sources whence Gold was collected in the Manzanita Mine from 1877–1882.

	1877.			1878.			1879.			1880.			1881.			1882.		
	2,100-ft. Block-paved Sluice. 4,200-ft. Rock paved Sluice.			2,300-ft. Block-paved Sluice. 4,200-ft. Rock-paved Sluice.			2,600-ft. Block-paved Sluice. 4,200-ft. Rock-paved Sluice.			2,900-ft. Block-paved Sluice. 4,200-ft. Rock-paved Sluice.			3,200-ft. Block-paved Sluice. 4,200-ft. Rock-paved Sluice.			3,400-ft. Block-paved Sluice. 4,200-ft. Rock-paved Sluice.		
		Per cent. of U. C. yield.	Per cent. of Total.		Per cent. of U. C. yield.	Per cent. of Total.		Per cent. of U. C. yield.	Per cent. of Total.		Per cent. of U. C. yield.	Per cent. of Total.		Per cent. of U. C. yield.	Per cent. of Total.		Per cent. of U. C. yield.	Per cent. of Total.
Block pavement........	$98,320 10	...	63.1	$106,038 48	...	61.	$142,787 79	...	69.4	$117,205 87	...	76.9	$158,431 74	..	77.6	$175,962 73	...	78.
Rock pavement........	42,861 00	...	27.6	52,178 53	...	30.1	44,551 80	...	21.6	25,330 00	...	16.7	34,000 00	...	16.6	33,914 00	...	15.
Undercurrents.																		
No. 1...............	.....	...	...	3,149 78	20.2	...	4,529 90	24.5	...	2,550 00	26.1	...	2,545 00	21.4	...	3,466 00	22.1	...
" 2......	....	...	...	2,056 46	13.2	...	2,428 40	13.1	...	1,412 50	14.4	...	1,686 00	14.2	...	2,070 50	13.4	...
" 3......	....	...	...	1,718 06	11.	...	2,219 25	12.	...	1,250 00	12.8	...	1,340 00	11.3	...	2,045 00	13.1	...
" 4...............	....	...	...	1,692 03	11.	. .	1,821 30	9.9	...	1,093 75	11.2	...	caved	...	...	410 00	2.6	...
" 5...............	....	...	...	1,197 43	7.7	...	1,284 25	7.	...	775 00	7.9	...	1,286 00	10.9	...	1,342 50	8.5	...
" 6..............	....	...	...	937 12	6.	...	1,354 30	7.3	...	318 75	3.2	...	*1,920 00	16.2	...	2,098 50	13.4	...
" 7..............	....	...	...	1,249 50	8.	...	1,237 55	6.7	...	531 25	5.4	...	820 00	6.9	...	1,112 50	7.1	...
" 8 and secondary..	....	...	...	1,015 22	6.5	...	934 00	5.	...	500 00	5.1	...	625 00	5.2	...	770 00	4.9	...
" 9......	....	...	...	885 06	5.7	...	1,120 80	6.1	...	581 25	6.	...	841 00	7.	...	972 00	6.2	...
Nos. 10 and 11 and secondary..........	....	...	...	1,666 12	10.7	...	1,564 45	8.4	...	762 50	7.9	...	†821 00	6.9	...	1,009 50	6.4	...
Sumps.................	....	...	...	....	...	...	....	...	...	....	...	...	....	...	...	370 00	2.3	...
Total yield of undercurrents	$14,532 00	...	9.3	$15,566 78	100.	8.9	$18,494 20	100.	9.	$9,775 00	100.	6.4	$11,884 00	100.	5.8	$15,666 50	100.	7.
Total yield of bullion...	$155,713 10	...	100.	$173,783 79	...	100.	$205,833 79	...	100.	$152,310 87	...	100.	$204,315 74	...	100.	$225,543 23	...	100.

MEM.—All the undercurrents were originally 20 ft. wide and 42 ft. long.
† Secondaries to Nos. 10 and 11 washed off by high water.
Since 1881 all of these undercurrents have been paved with blocks set on end, 4″×4″, spaced ⅞″ apart.

* No. 6 increased to 30 ft. in width and to 56 ft. in length.

TABLE XXXIV.

Statement showing Sources whence Gold was collected in the French Corral Mine from 1877–1882.

	1877.			1878.			1879.			1880.			1881.			1882.		
	1,700-ft. Block-paved Sluice. 2,300-ft. Rock-paved Sluice.			1,900-ft. Block-paved Sluice. 2,300-ft. Rock-paved Sluice.			2,200-ft. Block-paved Sluice. 2,300-ft. Rock-paved Sluice.			2,450-ft. Block-paved Sluice. 2,300-ft. Rock-paved Sluice.			2,500-ft. Block-paved Sluice. 2,300-ft. Rock-paved Sluice.			3,000-ft. Block-paved Sluice. 2,300-ft. Rock-paved Sluice.		
		Per cent. of U. C. yield.	Per cent. of Total.		Per cent. of U. C. yield.	Per cent. of Total.		Per cent. of U. C. yield.	Per cent. of Total.		Per cent. of U. C. yield.	Per cent. of Total.		Per cent. of U. C. yield.	Per cent. of Total.		Per cent. of U. C. yield.	Per cent. of Total.
Block pavement...... } Rock pavement...... }	$187,695 30	...	84.	$287,580 13	...	79.	$183,965 10	...	71.6	$170,459 15	...	75.6	$148,592 06	.	76.1	$150,976 68	...	79.4
				28,403 44	...	7.8	35,945 00	...	14.	24,500 00	...	10.9	10,593 64	..	10.1	19,353 76	...	10.2
Undercurrents:																		
No. 1..........	....	...	...	8,746 02	18.2	...	6,984 25	18.9	...	6,038 80	19.8	.	5,62[illegible]	[illegible]	...	*5,112 25	25.8	...
" 2 and secondary..	....	...	...	8,568 44	17 8	...	5,937 75	16.	...	5,164 60	17	.	4,[illegible]4 0[illegible]	15.	...	2,726 75	13.7	...
" 3..	. .....	...	...	7,125 56	15.	...	4,732 00	12.8	...	4,054 50	13.3	.	3,457 00	12.8	...	2,414 75	12.1	...
" 4................	....	...	...	4,417 40	9.2	...	3,458 00	9.3	...	2,808 60	9 2	...	2,423 00	8.9	...	1,839 50	9.3	..
" 5................	....	...	...	4,395 20	9.1	...	3,776 50	10.2	...	2,864 40	9.4	...	2,104 00	7.8	...	1,566 50	7.9	..
" 6................	....	...	...	3,240 91	6.7	...	2,548 00	7.	...	2,114 20	7.	. .	1,605 00	6.	...	1,134 25	5.7	...
" 7 and secondary .	....	...	...	4,350 81	9.	...	3,708 25	10.	...	2,523 40	8.2	...	2,104 00	7.8	...	1,485 25	7 5	...
" 8............. ..	....	...	...	3,129 92	6.5	...	2,388 75	6.4	...	2,126 60	7.	...	1,713 00	6.3	...	1,215 50	6.1	...
" 9 and secondary .	....	...	...	2,708 16	5.6	...	2,184 00	5.9	...	1,729 80	5.6	...	1,648 00	6.1	...	1,212 25	6.1	...
" 9½..............	....	...	...	....	...	...	....	...	...	40 30	.1	...	737 00	2.7	...	685 75	3.4	...
" 10..............	....	...	...	1,309 68	2.7	...	1,296 75	3.5	...	1,050 90	3.4	...	534 00	2.	..	†447 75	2.4	...
Sumps	....	...	...	....	...	...	....	...	...	....	...	...	1,035 00	3.8	...	....	...	...
Total yield of undercurrents.............	$35,308 00	...	16.	$47,992 10	100	13.2	$37,014 25	100.	14.4	$30,516 40	100.	13.5	‡$27,045 50	100.	13.8	§$19,870 50	100.	10.4
Total yield of bullion..	$223,003 30	...	100.	$363,975 67	...	100.	$256,924 35	...	100.	$225,475 55	...	100.	$195,231 18	...	100.	$190,200 94	...	100.

Mem.—All of the above undercurrents were originally 20 ft. wide and 42 ft. long. * No. 1 increased to 30 ft. in width. † No. 10 increased to 30 ft. in width
‡ The sumps and cuts at undercurrents were all thoroughly cleaned, for the first time, when the mine was idle in 1881.
§ Secondaries were not cleaned up in 1882, and only a few of the chutes.
Since 1881 all of these undercurrents have been lined with blocks 4″×4″ set on end, spaced ⅞″ apart. Grade of undercurrents, 8⅓ per cent.

TABLE XXXV

Statement showing Sources whence Gold was collected in the North Bloomfield Mine from 1876 to 1882.

	1876.		1877.		1878.		1879.		1880.		1881.		1882.	
	1,800-ft. Sluice in Tunnel. 300-ft. Sluice in Cañon.		1,800-ft. Sluice in Tunnel. 300-ft. Sluice in Cañon.		1,700-ft. Sluice in Tunnel. 300-ft. Sluice in Cañon.		1,600-ft. Sluice in Tunnel. 150-ft. Sluice in Cañon.		1,400-ft. Sluice in Tunnel. 150-ft. Sluice in Cañon.		1,400-ft. Sluice in Tunnel. 150-ft. Sluice in Cañon.		1,500-ft. Sluice in Tunnel. 150-ft. Sluice in Cañon.	
		Per Cent.		Per Cent.		Per Cent.		Per Cent.		Per Cent.		Per Cent.		Per Cent.
From undercurrent No. 1. {24′ wide, 48′ long}	$2,369 66	45.2	$4,156 35	44.6	$2,539 50	30.8	$3,600 00	31.3	$3,156 00	30.3	$3,180 00	29.4	$5,365 18	34.9
From undercurrent No. 2, from one Grizzly. {24′ wide, 24′ long}	½ yr. 841 00	16.	1,798 70	19.3	1,133 00	13.7	2,100 00	18.2	1,903 50	18.3	1,800 00	16.6	2,771 07	18.1
From undercurrent No. 3, from one Grizzly. {24′ wide, 36′ long}	½ yr. 521 00	10.	1,625 70	17.4	1,127 00	13.7	2,100 00	18.2	1,791 00	17.2	1,500 00	13.9	1,851 00	12.
From undercurrent No. 4*. {18′ wide, 36′ long}	1,503 34	28.8	920 98	9.9	982 00	11.9	900 00	7.8	657 00	6.3	620 00	5.7	768 97	5.
From undercurrent No. 5*, from one Grizzly. {24′ wide, 24′ long}	....	....	½ yr. 442 07	4.7	972 00	11.8	1,000 00	8.7	805 50	7.7	1,075 00	10.	1,455 76	9.4
From undercurrent No. 6*, from one Grizzly. {24′ wide, 36′ long}	....	...	½ yr. 381 20	4.1	549 50	6.6	960 00	8.4	561 00	5.4	750 00	7.	771 90	5.
From undercurrent No. 7†. {54′ wide, 48′ long}	....	....	....	....	947 00	11.5	850 00	7.4	1,105 50	10.6	1,250 00	11.6	1,643 60	10.7
From undercurrent No. 8†. {48′ wide, 48′ long}	....	....	....	....	....	....	....	....	433 50	4.2	625 00	5.8	741 92	4.9
		100.		100		100.		100.		100.		100.		100
Total from undercurrents..............	5,235 00	2.72	9,325 00	3.27	8,250 00	2.65	11,510 00	3.52	10,413 00	3.61	10,800 00	4.56	15,369 40	3.98
From Tail Sluice in Cañon.............	1,800 00	.94	8,200 00	2.82	3,780 00	1.21	2,500 00	.76	2,000 00	.70	1,000 00	.42	4,542 85	1.17
From Tunnel below Flumes:														
From above No. 6 Shaft	....	....	....	....	....	....	3,000 00	....	4,350 00	....	2,490 00	....	3,345 30	...
From No. 6 to No. 4 Shaft...........	....	....	.. ..	....	....	....	1,200 00	....	5,075 00	...	3,289 00	....	3,480 00	...
From No. 4 to No. 2 Shaft...........	....	....	....	....	....	....	5,900 00	....	9,475 00	....	4,290 00	...	5,985 00	....
From No. 2 to Tail Sluice...........	....	....	....	....	....	....	2,400 00	....	9,400 00	....	11,631 00	....	14,989 70	....
Total from crevicing below Tunnel Sluice......	7,290 00	3.78	8,250 00	2.84	16,500 00	5.30	12,500 00	3.82	28,300 00	9.83	21,700 00	9.16	27,800 00	7.20
From Cuts above Tunnel Sluices.......	1,510 00	.79	11,500 00	3.92	14,218 54	4.57	22,500 00	6 88	26,400 00	9.13	11,700 00	4.93	44,000 00	11.39
From Sluices in Tunnel and above.....	176,900 73	91.77	253,500 42	87.15	268,528 16	86.27	277,749 76	85.02	220,811 18	76.73	189,535 14	79.99	294,433 98	76.2
Cleaning Bed-rock	....	.. .	... ...	....	....	....	....	....	....	....	‡2,200 00	.94		
Total yield..................	$192,735 73	100.	$290,775 42	100.	$311,276 70	100.	$326,751 76	100.	$287,924 18	100.	$236,935 14	100.	$386,146 23	100.

* The tailings from undercurrent No. 4 do not run through 5 and 6.

† The tailings from undercurrent No. 7 do not run through No. 8.

‡ Cleaning bed-rock

CHAPTER XVIII.

LOSS OF GOLD AND QUICKSILVER.

Loss of Quicksilver.—There is an unavoidable loss of quicksilver, the amount of which depends on the character of the gravel washed, the quantity of water used, the grade, length, and condition of the sluices, and the number of days run. The use of a long line of sluices, kept in good order, and the employment of undercurrents, tend to diminish it.

La Grange.—The aggregate amount of quicksilver lost at the La Grange Hydraulic Company's mine in running six claims, during a period of two and a half years, aggregating 1,520* days (24 hours each), washing and moving 2,275,967 cubic yards of gravel, and using 1,533,728 miner's inches of water (2,159 cubic feet each), was 553.75 pounds.

The exact loss of quicksilver during four years' work on the various claims of this company amounted to 1,200 pounds.

North Bloomfield.—For the year ending November 3, 1875, the North Bloomfield claims used 464,600 miner's inches of water (2,230 cubic feet each), and 9,649 pounds of quicksilver were employed in the sluices.

The loss of quicksilver at the respective claims was as follows:

Name of Claim.	Miner's inches used.	Length of Sluice.	Loss of Quicksilver.	
		Feet.	*Lbs.*	*Per ct.*
No. 8	386,972	1,800	900	11
Woodward	51,550	600	217	25
Eisenbeck	26,000	400	125	25

* The aggregate number of days' work of all the claims.

The large losses at the Woodward and Eisenbeck claims are attributed to old and poor sluices and steep grades. For the year ending October 31, 1876, the loss of quicksilver at the same claims was as follows:

Name of Claim.	Miner's inches used.	Length of Sluice.	Loss of Quicksilver.
		Feet.	*Lbs.*
No. 8	700,000	1,800	2,251
Woodward	30,000	600	123
Eisenbeck	56,200	400	182

In 1882 the loss of quicksilver at the North Bloomfield mines, with a use of 1,000,000 inches of water, was 3,390 pounds.

The following table shows the total number of inches of water run, total corresponding amount of gold collected, and loss of quicksilver at the North Bloomfield mine from 1876 to 1882 inclusive:

TABLE XXXVI.

	Water used. Inches.	Bullion produced.	Loss of Quicksilver.
1876	740,650	$200,366 54	21,512 lbs.
1877	535,450	292,382 95	
1878	793,999	312,279 97	
1879	918,983	331,759 76	
1880	863,820	287,924 18	
1881*	744,600	236,935 14	
1882	988,250	386,146 23	
	5,585,752	$2,047,794 77	

In rock sluices which are run long periods without cleaning up the loss of quicksilver is very great. The 24-foot undercurrents at French Corral and Manzanita mines

* Shut down by injunction four months.

are estimated to lose from 7 to 8 pounds of quicksilver per run of 10 weeks.

Delaney and New Kelley Claims.—The annexed table shows a run at the Delaney and New Kelley claims, in Stanislaus County, where the grades are light; the details give the amount of quicksilver charged, loss of quicksilver, quantity of water used, and the cubic yards of gravel mined, with all attendant costs.

There was more water used in the Delaney than in the Kelley, and the sluices of the former are much shorter than those of the latter. The composition of the amalgam obtained at the Delaney was as follows:

Quicksilver	65.19	per cent.
Gold	34.81	"
Total	100.00	"

One hundred and fifty-eight pounds of this amalgam were retorted, from which 90 pounds of quicksilver were distilled, showing a loss of 12.62 per cent. The retorted gold weighed 55 pounds, and, after melting, 52 pounds—a decrease in the weight (from slagging off impurities, lead, etc.) of three pounds, or 5.76 per cent. The fineness of this bullion was .895.

Loss of Gold.—The most efficient means of saving gold from cement gravel are a liberal use of the best shattering powder, breaking the cement before it is washed, and the introduction of several "drops," when possible, along the line of the sluices. Frequent drops and short lines give better results than a long, continuous line.

Gravel moving in sluices is subjected to a grinding and scouring process which alone is not sufficient to disintegrate the cement gravel unless the sluices are of great length. The lessening of grades and the use of undercurrents tend to diminish the loss of fine gold. Extensive lines of sluices and undercurrents are expensive to build and keep in repair. Like the last concentrator, the last undercurrent will always catch some metal.

TABLE XXXVII.

Name of Claim.	No. of Days' Runs.	Miner's Inches Used.	Length of Sluice.	Cubic Yards of Gravel Washed.	Cost of Labor.	Yield of Amalgam.	Yield of Gold.	Value of Gold.	Quicksilver used in Run.	Quicksilver cleaned up after Run.	Quicksilver Lost.	
			Feet.			*Lbs. avdp.*	*Lbs.*		*Lbs.*	*Lbs.*	*Lbs.*	*Per ct.*
Delaney	65	106,200	$445\frac{1}{2}$		$3,294 60	213	71.15	$19,084 93	$1,657\frac{1}{2}$	$1,555\frac{1}{4}$	$102\frac{1}{4}$	$6\frac{1}{10}$
New Kelley..	68	81,600	1,776	98,538	4,331 50	84	30.35	8,140 93	$879\frac{3}{4}$	$840\frac{1}{4}$	$39\frac{1}{2}$	$4\frac{3}{8}$

NOTE.—The Delaney sluices were set originally on a grade of 3 in. to 16 ft., which was changed subsequently to $3\frac{1}{8}$ in. to 16 ft., and, with the same amount of water and the same sluices, the amount of gravel moved was thereby increased (rough estimate) about one-third. The gravel was of an ordinary light character, the largest rocks being about the size of cobble-stones. Height of banks, from 25 to 65 feet.

The Delaney Run commenced August 7, 1877, and ended December 14, 1877.

The New Kelley Run commenced August 4, 1877, and ended December 17, 1877.

While the knowledge of the quantity of gold in gravel banks remains as imperfect as it is at present, the simple and well-known appliances now in use are the most convenient and economical, and the excuse so often given for small yields—viz., loss of microscopic gold, and bad sluices—can be set down as one of the preliminary indications of a bad investment.

The loss of quicksilver in sluices would seem to involve the loss of gold, but it is practically impossible to determine to what extent this is the case. There are many conflicting opinions as to the amount of fine, floured, and "rust" gold which escapes, but in properly constructed sluices the appliances already known save all that can be economically or profitably caught.

In substantiation of this can be cited the work done in 1872–6 at Gardner's Point. The number of inches of water used at the claim during this period is not known. The number of cubic yards of gravel moved has been approximated from the best obtainable data and an inspection of the property. From 1872 to 1874, inclusive, about 148,000 cubic yards of dirt were mined. In 1875 the claim was run full time only fourteen days. In 1876, 40,000 cubic yards of gravel and 260,000 cubic yards of lava ashes were washed. The gross yield from 1872 to 1876 was $140,000.

The tailings from all these washings were caught and confined in a ravine situated a short distance below the claim. The length of the sluices through which the gravel passed was 1,378 feet, with three undercurrents. In 1876 the ravine, supposed by many to be exceedingly rich, was cleaned up, and its gross yield was $1,168, not one per cent. of the total receipts from the washings.

CHAPTER XIX.

THE DUTY OF THE MINER'S INCH.

THE quantity of material that is washed by an inch of water in twenty-four hours is called its "duty." Estimates of the average duty have of necessity differed greatly, since the inch itself denotes a varying discharge of 1.20 to 1.76 cubic feet per minute in different parts of the State. Therefore the determination of the "duty" is good only for the specific condition under which it is made.

The circumstances by which it is affected are, the quantity of water, character of the material washed, height of banks, use of explosives, size and grade of sluices, and class of riffles. The sluice affects the duty of the inch in so far as its capacity regulates the quantity washed.

The banks of the mines which discharge their tailings into the American River consist principally of small, fine sediment, disintegrated rock, and materials which are easily moved. The duty of the inch in this locality is assumed by the State Engineer to be 4½ cubic yards; while at Dutch Flat, in the deep washings, he found it to average only from 1.4 to 2 cubic yards.

The duty of the inch in the mines which "tail" into the Yuba River is estimated by the same authority to be 3.5 cubic yards. The gravel deposits here are composed of all grades of material.

The following table from Lieutenant-Colonel Mendell's report shows the State Engineer's estimates of the duty of the inch in various localities:

TABLE XXXVIII.*

Name of Streams.	Quantity of Water used in Mining and discharged into beds of rivers in 24 hours.	State Engineer's Estimate of the Duty per Inch.	Amount moved.
	Inches.	*Cubic Yards.*	*Cubic Yards.*
Table Mountain, or Dry Creek.........	833,250	3½	2,916,375
Butte Creek	24,000	3	84,000
Feather River........	1,259,363	3½	4,407,770
Yuba River..........	5,458,171	3½	19,103,598
Bear River..... ...	1,117,082	3	3,351,246
Dry Creek No. 2.....	44,229	3	132,687
American River......	1,914,500	4½	8,615,250
Total	10,650,595	3.6	38,610,926

The average duty of the miner's inch in the deposits mined and discharged into the San Joaquin and its tributaries, according to Lieutenant A. W. Payson, Corps of Engineers, U. S. A., is shown in Table XXXIX.

In discussing the subject Lieutenant Payson says: "I have thought it fair to allow for the larger hydraulic mines 2½ yards per inch; for the 'Jenny Lind' and many of the smaller claims with low banks, deficient head, grade, and water-supply, 2 yards; while in numerous instances of placer, river, and drift mining, where excavated material is thrown into sluice-boxes, I have varied the amounts according to my knowledge of the circumstances. . . . The quantity for Calaveras is based on the probable future water-supply."

From empirical data at the Jenny Lind claim, with a grade of the tail sluices of $\frac{1}{30}$ to $\frac{1}{36}$, the quantity moved was estimated at 2.4 yards per inch. The material was coarse cemented gravel which required the use of powder.

At Cherokee Flat, with generally very fine material, high banks, head of 300 to 350 feet, and grade $\frac{1}{32}$, 5.5 cubic yards are reported by the superintendent as the duty of the inch.

* See also Report State Engineer, 1880, part iii. p. 24.

TABLE XXXIX.

Lieut. Payson's Estimate of the Duty of the Inch.

River.	Mine.	Ditch.	Water used, twenty-four hours.	Cubic yards moved per twenty-four hours per inch.	Total number cubic yards moved.	Summary.	Remarks.
			Inches.			*Cubic yds.*	
Cosumnes	Hill Top	American and Sacramento.	456,000	2½	1,140,000	....	Much heavy material stored in ravine.
	Various placers	Jordan	48,000	....	40,000	1,180,000	Part of water used for power.
Dry Creek	Irish Hill	American and Sacramento.	162,000	2½	405,000	405,000	Little now reaches any river.
Mule Creek	Various small placers	Johnson's	38,000	1	38,000	38,000	
Sutter Creek	Various placers and hydraulic	Amador Canal	54,750	1	54,750	....	
	Volcano hydraulic	Volcano	365,000	2½	912,500	... .	Not now working dump in bed of dry creek.
	Various placers	Johnson's	38,000	1	38,000	1,005,250	
Jackson Creek.	Various placers and hydraulic	Amador Canal Company	127,750	1	127,750	....	
	Near Buena Vista, at head of Jackson Creek	Dougherty	43,400	1	43,400	171,150	
Mokelumne	Near Campo Seco, Camanche, and Stockton Ridge	Mokelumne	61,000	2	122,000	....	Bulk of heavy material stored in ravines. Part of water used for power.
	Railroad Flat, head South Fork	Clark's	45,000	2	90,000	....	
	Near Lancha Plana and Camanche.	Murray & Dougherty's	118,500	...	60,000	272,000	
Calaveras	Near Jenny Lind	Salt Spring Valley Reservation and Union	365,000	2	730,000	....	Formerly in main stream. Heavy material now mostly stored.
	Chile Gulch and Jesu Maria Fork of Calaveras	Mokelumne	200,750	2½	501,875	....	In bed of streams.
	Juniper, at Dogtown, San Domingo Creek	Union	365,000	2½	912,500	....	
	Near Mokelumne Hill	Cook Brothers	45,000	2	90,000	2,234,375	
Stanislaus	Near Knight's Ferry	(small)	38,720	2	77,440	77,440	In main rivers.
Tuolumne	La Grange and Patricksville	La Grange	812,500	*2½	2,031,250	2,031,250	
	Total		3,384,370	2.2	7,414,465	....	

* This is too high. An allowance of 1½ cu. yds. would be liberal.

At Dutch Flat, in Nevada County, the duty of the miner's inch has been estimated* at certain mines to be as follows:

TABLE XL.

Name of Mine	Inches of Water used.	Total Cubic Yards moved.	Cubic Yards moved per Inch of Water.
Southern Cross..............	299,144	598,050	2.02
Polar Star..................	412,070	618,130	1.49
Franklin....................	91,409	326,147	3.4
Cedar Claim.................	247,062	2,057,400	7.50

In the State Engineer's report the estimates are undoubtedly the results obtained after careful investigation of the subject; but, unfortunately, the quantity of water, grades and size of the sluices, and character of the riffles are not given.

According to Le Conte,† "if the surface of the obstacle is constant, the force of running water varies as the square of the velocity, the transporting power of a current varying as the sixth power of the velocity; but the power of removing material will vary between the square of the velocity and the sixth power of the velocity."

The transporting power (as used by Le Conte) and the transporting capacity are terms which must not be confounded. Transporting capacity denotes the amount of material which running water carries along per unit of time.

The transporting capacity of sluices is generally greater (comparatively) than that of rivers, on account of the usually heavier grades (from 200 to 300 feet per mile), regularity of cross sections, and character of the bottom and sides of the former.

In sluices where the riffles are blocks a larger amount of material is moved than where rock riffles only are employed. An increase in the grade of a sluice would necessarily increase its carrying capacity.

* By the State Engineer, W H. Hall, State of Cal. *vs.* Gold Run Ditch and Mining Co.

† "Elements of Geology," Jos. Le Conte, pp. 19, 20.

The dirt as it enters the sluice has its lighter portion taken up and carried in suspension by the current, whilst the coarse and heavy material moves along on, and in part above, the riffles, but below the surface of the water. Boulders and rocks move down the sluices with varying velocities and in different directions as they advance, aiding in stirring and disintegrating the cement gravel and earthy stuff, which little by little fall to pieces and into particles that, segregated as light material, rise towards the surface of the water. The rocks and boulders travelling over the riffles assist in keeping the material thoroughly agitated in the sluices, where it is alternately changing position from the bottom to the top, until it is finally discharged.

The material, wearing down as it advances, is kept from packing by the presence of the rolling rocks which still maintain their solidity. Light, sandy gravel requires very wide and shallow sluices, as it cannot be washed advantageously in deep sluices, unless by a proper mixture of rocks, which permits the use of a greater quantity of water, so that the capacity of the same sluice is increased.

A heavy grade will compensate for a limited supply of water. With an abundant supply of water and material, the capacity of sluices will depend upon:

1st. The character of the material washed;

2d. The size and minimum grade of the sluices;

3d. The character of the riffles used.

The statement of some engineers that the transporting power (meaning capacity) of a sluice increases with the third power of its grade is not verified by the comparative tests which have been recorded. However, these tests, which give the only reliable data extant, were not made with the same material, so there is still a very important factor undetermined.

The empirical results thus far obtained demonstrate that the transporting capacity of a sluice set on a 2.08 per cent. grade, and that of a sluice on a 4½ per cent. grade,

vary as the 1.52 to the 1.87 powers of these grades. How this will agree with the results obtained from properly conducted experiments on increasing from 4 or 4½ to 8 or 9 per cent. grades remains to be ascertained. Mr. Hamilton Smith, Jr., considers that under these circumstances the transporting power (capacity) of the sluice will increase about with the square of the inclination.

Mr. P. M. Randall says that the transporting power (capacity) of water is as the 3.75 power of the velocity.

From official data of the Blue Tent Company of the amounts of light material washed on a 10½ per cent. grade, it would appear that the transporting capacity for such material varies as the 1.20 power of the grade.

The time, means, and facilities for the careful and thorough investigation and determination of the duty of the miner's inch have not as yet been afforded to the engineers who have been appointed for this purpose. In most cases the amounts of material estimated to have been removed may be considered as mere approximations, as is evidenced by the wide differences in the many estimates which are given in the various publications.

In the suit of the State of California *vs.* the Gold Run Ditch and Mining Company the estimates of the amounts of material washed and remaining, made by the various engineers who had investigated the subject, showed differences as great as 33 per cent. where the question of size of excavations and cubic contents was alone at issue. The difference arose largely from attempts to reconstruct from insufficient data the former topography of the land mined, no accurate information upon the point being obtainable.

The only known attempts at any extended and detailed investigation of the duty of the miner's inch have been made by the North Bloomfield and the La Grange Hydraulic Mining Companies. The results of the work performed at these mines are given in the annexed tabulated statement:

TABLE XLI.

Duty of the Miner's Inch.

A. North Bloomfield Mine.

Years.	Cubic yards of Gravel washed.	Miner's 24-hour inches.	Grade.	Cubic yards washed per Miner's inch.	Cubic ft. of Water used per cubic ft. of Gravel moved.	Height of Bank.	Remarks
1870 to 1874	3,250,000	710,987	....	4.6	18.	100 ft.	Sluices 6 ft. wide and 32 in. deep. Riffles principally blocks, but rock-riffles in the tail-sluices. The larger portion of the material moved was top gravel.
1875.......	1,858,000	386,972	6½ in. to 12 ft.	4.8	17.	100 "	
1876.......	2,919,700	700,000	" "	4.17	20.	200 "	
1877... ..	2 993,930	595,000	" "	3.86	21.	265 "	
Totals....	11,021,630	2,392,959	....	4.6	18.	.....	

B. La Grange Mines.

Years.	Name of Claims.	Cubic yards of Gravel washed.	Miner's 24-hour inches.	Grade.	Cubic yards washed per Miner's inch.	Cubic ft. of Water used per cubic ft. of Gravel moved.	Height of Bank.	Remarks.
1874 to 1876	French Hill.	676,968	624,745	4 in. to 16 ft.	1.08	74.	10 to 48 ft.	Sluices 4 ft. wide and 30 in. deep, paved with blocks.
1875 " 1876	Light.......	683,244	375,155	" " "	1.82	43.9	60 "	
1874 " 1876	Chesnau....	284,932	207,010	" " "	1.37	58.	50 " 80 "	
1875 " 1878	Kelley.. ..	459,570	302,960	" " "	1.52	52.	40 " 50 "	
1880 " 1881	Vigno Hill..	329,120	203,325	" " "	1.57	50.	10 " 80 "	

Tab ing, from May 30, 1874, to October 12, 1876.

Year.	Run commenced.	Months.	End of Run.	e Yard. Water.	Melting and Refining.	Total Cost.	Bullion Yield. Amalgam. Lbs. Avoirdupois.	Weight before Melting. Lbs. Avoirdupois.	Fineness. Gold.	Fineness. Silver.	Value of Gold.	Value of Silver.	Total amount of Bullion Produced.
1874	30	May	..	.									
		June	..	...	......	...		....	.	.	... ..	...	...
		July ..	6	...	......	....	...		..	..	... ..	....	. .
	15	Aug.	..	017	...	$0 109	121.00	48.00	.921	..	$13,304 29	$39 29	$13,343 58
		Sept.	..	...	....	...	..	...	..	..	......	....	....
	3	Oct	1	...	....	....	...	..		..	... ...	...	...
	27	Nov.	26	009	....	054	58.00	23 00	.936	.055	6,411 13	15 49	6,426 62
		Dec.	..	010	....	059	70.00	25.75	.934	.051	7,220 39	19 99	7,240 38
1875		Jan	..	...	....	.. ..	....	..	..	..	......	....	...
	23	Feb.	21	...	....	....	....	..	..	..	......	.. .	...
		March..	..	...	....	....	117.25	43.31	.938	.054	12,050 93	29 07	12,080 00
		April...	..	...	....	....	....	....	..	..	......	....	...
	29	May....	28	...	....	....	. ..	...	..	..	......	....	....
		June....	.	...	....	....	103.50	37.25	.921	.056	10,366 59	30 49	10,397 08
	15	July	14	. .	....	.	...	...	..	.	......	....	.....
		Aug.	.	. .	....	. ..	30.00	10.50	.928	.055	2,891 58	8 10	2,899 68
	0	Sept.	8	...	$0 0004	....	....	....	..	..	......	....	...
	14	Oct	13	...	....	.	73.75	26.68	.951	.047	7,545 31	15 80	7,561 11
		Nov.	..	008	....	059	17.31	6.44	.941	.052	1,818 34	5 05	1,823 39
	3	Dec	2	...	....	..	..	...	..	..	. . ..	. .	....
1876		Jan	31	...	..	..	46.00	15.44	.919	.057	4,462 84	20 49	4,483 33
	1	Feb.	..	...	....	.	63.12	22.68	.940	.050	6,121 73	15 00	6,136 73
		March..	..	...	....	....	.	. ..	..	..	......	....	..
	25	April...	24	...	...	....		.. .	..	..	......	....	.
		May	.	...	....	....	105.25	36.44	.936	.052	10,151 95	27 00	10,178 95
	8	June ..	7	...	....	..		....	..	..	......	. .	.
		July	..	...	...	..	31.75	12.09	.936	.054	3,325 67	8 91	3,334 58
		Aug.	..	...	....	..		..	..	..	.... .	...	... .
		Sept.	..	...	...	. .		. .	..	..	.....	....	....
		Oct	12	..	....	....		.	..	..	.. ..	.	...
				01	....	046	42 00	15.25	.926	.059	4,269 76	11 00	4,280 76
....	..	.....	..	0104	$0 0004	$0 063	878 ..	... 83	..	..	$89,940 51	$245 68	$90,186 19

ed yielded 13.8 cents per cubic yard

Tabular Stat[illegible]om February 12, 1875, to September 26, 1876.

Year.	Run Commenced.	Months.	End of Run.	Days.	Washings.	[illegible]rd. Melting and Refining.	Total Cost.	Bullion Yield. Amalgam. Pounds Avd'ps.	Weight before Melting. Lbs. Avoirdupois.	Fineness. Gold.	Fineness. Silver.	Value of Gold.	Value of Silver.	Total amount of Bullion Produced.
1875	12	Feb....	..	...		......	..	...	....	..	..	... ..	.. .	..
		March..	..	..		....	....	.. .	..	.	..	.... ..	...	. . ..
	23	April...	22	46	2	....	....	51.00	18.15	935	.052	$5,115 15	$11 13	$5,126 28
		May ...	..	....		....	...	....	....	..	..	......	....	.. ..
	4	June...	3	30		....	...	27.25	10.60	.950	..	2,926 47	6 65	2,933 12
	16	July ...	15	32	1	...	$0 035	32.00	11.20	.928	.055	3,084 63	8 26	3,092 89
		Aug....	..	....		....	.. .	.. .	. ..	..	..	. . ..	....	......
	11	Sept....	10	49		....	....	59.00	21.35	.951	.047	6,035 55	15 00	6,050 55
	15	Oct....	14	24		....	...	35.81	13.33	.941	052	3,765 64	8 55	3,774 19
		Nov....	..	...		.. .	....	..	.	..	..	......	...	... ..
	2	Dec ...	1	20		$0 0003	. .	31 00	10 41	942	054	2,760 89	10 05	2,770 94
1876		Jan....	.	..		..	. .	.	....	..	..	......	. ..	. . ..
	7	Feb....	6	44		.. .	038	72 53	26.06	.940	050	7,426 10	18 81	7,444 91
		March..	..	....		....	...		.. ..	..	..	......	....	... ..
	26	April...	25	70		....	048	100 25	30.70	936	.052	10,249 70	27 00	10,276 70
		May ...	.	....		.. .	...		....	.	..	... ..	....	.. ..
		June. .	..	....		. .	..	.	.	.	.	. .	. ..	.. ..
		July ..	..	....		....	...		..	..	..	.....	....	.
		Aug....	..	...		....	...		.		..	.... ..	. ..	.. ..
		Sept....	26	48	11	...	048	[illegible]9 50	15.00	.880	064	3,963 41	11 66	3,975 07
....	..	......		376	1	$0 0003	$0 038	454.34	162 89	.	..	$45,327 54	$117 11	$45,444 65

Tailing, from June 1, 1874, to October 3, 1876.

Year.	Run Commenced.	Months.	End of Run.	Yard. Water.	Yard. Melting and Refining.	Total Cost.	Amalgam. Pounds Avd'ps.	Weight before Melting. Lbs. Avoirdupois.	Fineness. Gold.	Fineness. Silver.	Bullion Yield. Value of Gold.	Bullion Yield. Value of Silver.	Bullion Yield. Total amount of Bullion Produced.
1874	1	June...	..	...	......	....	...	....	..	..	......	....	......
	4	July ...	3	004	....	$0 043	35 00	14.00	.943	047	$3,958 31	$9 03	$3,967 34
	17	Aug....	15	008	. ..	025	41 00	15.75	.944	..	4,506 97	6 11	4,513 08
		Sept....	28	007	....	052	52.25	19.73	936	.055	5,497 39	15 49	5,512 88
	2	Oct	..	...	...	.. .	..	....	..	..	......	....	... ..
	24	Nov....	23	005	....	040	63.75	21.88	.934	.051	6,134 53	19 09	6,153 62
		Dec....	..	...	....	. .	....	....	..	..	......	....	......
1875		Jan ...	..	...	....	...	...	. .	..	..	......	....	......
		Feb....	19	009	$0 0005	067	142 00	52.45	.945	.051	14,585 74	43 65	14,629 39
			.	...	....	.	....	....	..	..	.. ...	....	... ..
		March..	..	...	....	....	...	....	..	..	......	....	......
		April...	..	...	....	...	...	....	..	..	......	...	.. ...
1876	1	May....	..	...	....		...	....	..	.	.. ...	....	... ..
	6	June....	5	...	...	..	31.25	11.90	936	.054	3,273 29	8 88	3,282 17
		July....	..	009	...	055	...	...	..	..	......	....	......
	6	Aug....	5	...	. ..		63.00	24 50	.895	.068	6,544 73	20 58	6,565 31
		Sept....	.	...	....		. .	...	.	.	......	....	. ....
		Oct	3	013	....	[illegible]	31 00	11.25	.929	.059	3,147 36	10 58	3,157 94
....	..	....	..	008	$0 0005	$0 055	450 25	171.46	..	..	$47,648 32	$133 41	$47,781 73

Tabular[illegible]ng, from March 1, 1875, to December 16, 1875.

Year.	Run commenced.	Months.	End of Run.	Washings. Days.	Washings. Hours.	[illegible]bic Yard. Water.	[illegible]bic Yard. Melting and Refining.	Total Cost.	Amalgam. Lbs. Avoirdupois.	Weight before Melting. Lbs. Avoirdupois.	Fineness. Gold.	Fineness. Silver.	Bullion Yield. Value of Gold.	Bullion Yield. Value of Silver.	Bullion Yield. Total amount of Bullion Produced.
1875	1	March.	..	...		...	....	....	.		..		....	.	.
	22	April...	21	22	1[illegible]	...	...	...	20.2[illegible]	7 .0[illegible]	935	.05[illegible]	$2,020 2[illegible]	$7 30	$2,033 56
		May. ...	...	....		....	....	....	.	.	..	.	.. ..	...	....
	3	June...	2	27	[illegible]	....	.		1[illegible].50	5.[illegible]5	.050	..	1,447 97	4 75	1,452 72
	17	July ..	16	33	[illegible]	....	...	.	22.00	7 60	.028	.05[illegible]	2,00[illegible] [illegible]7	6 54	2,008 71
		Aug. ...	...	..	.	$0 006	$0 0004	$0 037	..	...	..	..	... .	...	..
	10	Sept....	[illegible]	24	1[illegible]	...	. .	...	1[illegible] 75	4 07	.051	047	1,404 14	4 35	1,408 49
	10	Oct	9	11	1[illegible]	...	.	..	5 31	1.98	.941	.05[illegible]	557 [illegible]	2 95	560 61
		Nov....	..	...		...	..	...	.	..	..	..	......	.	.....
		Dec....	1[illegible]	20	[illegible]	....	...		16 00	5.20	.935	.030	1,588 67	5 21	1,594 08
...	.	..	.	130	4	$0 006	$0 0004	$0 037	[illegible] 81	32 20	..	..	$9,117 17	$31 10	$9,148 17

Tabular S[illegible]r, from May 28, 1874, to January 21, 1875.

Year.	Run commenced.	Months.	End of Run.	Washings. Days.	Washings. Hours.	[illegible]Yard. Water.	[illegible]Yard. Melting and Refining.	Total Cost.	Amalgam Pounds Avd'ps.	Weight before Melting. Lbs. Avoirdupois.	Fineness. Gold.	Fineness. Silver.	Bullion Yield. Value of Gold.	Bullion Yield. Value of Silver.	Bullion Yield. Total amount of Bullion Produced.
1874	28	May ...	..	....	..		......	...	..	....	..	.	.	. .	..
		June...	..	....	..		......	..	.	..	..	.			.....
	14	July ...	3	17	18		....	$0 03[illegible]	32 00	11.75	943	.047	$3,3[illegible] 74	$0 00	$3,320 74
	13	Aug....	12	16	18	003	....		30.00	13 50	.940	..	.. .		3,801 11
		Sept....	24	15	17	007	.	074	32.50	12.27	936	.055	3,413 20	15 51	3,428 71
	5	Oct......		...	..	..	$0 0007	..	. .	. .	..	..	. .	.	..
	20	Nov....	18	19	22	003	....	046	43.25	14.85	934	[illegible]	4,158 40	18 96	4,177 36
		Dec....	..	....	..		.. .	...		. .	.	..	.		. .
1875		Jan. ...	21	37	10	003	. ..	032	53 00	19.57	.941	050	5,445 60	14 55	5,460 1[illegible]
....	..	.....	..	107	11	004	$0 0007	$0 039	196.75	71.94	..	..	$16,337 04	$58 02	$20,197 07

CHAPTER XX.

STATISTICS OF THE COSTS OF WORKING AND THE YIELD OF GRAVEL.

CORRECT statistics showing the costs, the quantity of material washed, and the corresponding yield of gold are rare and difficult to obtain. In the early days of placer-mining in California the question to be solved by the miner was not what the gravel would yield per cubic yard, and what it would cost to move it, but rather how many ounces of gold-dust he could "pan out" or "rock out" between sunrise and sunset. What the miner required was that the daily yield in *dust* should exceed the cost of living, etc. When it fell below this he moved his camp to other grounds.

The wonderful productiveness of the river bars and shallow placers, attested by the gold bullion and dust shipments, created an extravagance usual to all new and rich mining countries, the baneful effects of which are still felt.

As the richest and most easily worked placers became exhausted the increasing necessity of mining on an extensive scale and with ample capital led to the formation of large companies. Then became evident the importance of determining beforehand the amount of gold in the various claims and the costs of working them. This last included various engineering problems, as the best grades, the duty of the inch, etc. In this manner the first data concerning the yield (commonly estimated per cubic yard, but very often, for the sake of convenience, per inch of water) of the auriferous gravels were published. Many

of these were collected and printed in the reports of the U. S. Commissioner of Mining Statistics, and Prof. Whitney has added to them in his "Contributions to American Geology." Detailed investigations have been undertaken of late by the State Engineer of California and also by Lieutenant-Colonel Mendell, Corps of Engineers, U. S. A.

There is now obtainable quite a large amount of statistics in printed form; but to a great extent these are of no value, partly from their unreliability, partly from their insufficiency of detail. Miners and mining corporations as a rule object to making public anything concerning their property except what is absolutely necessary, and are apt, when pressed, to give ambiguous information. As it is impossible, after large areas of ground have been washed away, to accurately reconstruct their topography, all statistics of the cubic contents of excavations derived from surveys made after mining has ceased are unreliable.

The most reliable data are those of the North Bloomfield and the La Grange Hydraulic Companies, both of which have carried on their works in the most intelligent and satisfactory manner.

To better familiarize the reader with the subject of gravel-mining, and thus enable him to form an idea of the amount of water used per cubic yard of dirt moved, and of the corresponding yield and attendant costs, an exhibit of a claim running on an approximately minimum basis—viz., light pressures and smallest practicable grades—has been selected. For this purpose the claims of the La Grange Company have been chosen, as the yield per cubic yard and the grades there used can be considered as nearly the lightest with which an hydraulic claim can yield remunerative returns.

The annexed tabular statements show in convenient form the data alluded to.* The tables have been care-

* In obtaining the data for these tables I am greatly indebted to the valuable assistance of Mr. Joseph Messerer, superintendent of the La Grange Ditch and Hydraulic Mining Company.

fully arranged, and the data of the yield and disbursements are accurate. The apportionment of the material account has in some places been calculated from the general material account. The measurements of the ground washed were made at each clean-up, and subsequently the entire ground was resurveyed and the work checked.

TABLE XLVII.

Résumé of work done by the La Grange Co. on all its claims, June 1, 1874, to Sept. 30, 1876.

1,533,728 inches (2,159 cubic feet each) washed
2,275,967 cubic yards of gravel, which yielded
12,026.84 oz. Troy = $231,893.

DISBURSEMENTS.	Total.	Per cubic yard.	Per ounce metal produced.
Water	$17,307 62	$0 008	$1 43
Labor	82,345 70	0 036	6 85
Material	21,788 35	0 010	1 81
Official	11,244 94		0 94
Contingent	3,125 80	0 006	0 26
Taxes	1,130 41		0 09
Total	$136,942 82	$0 060	$11 38

Average value of the oz. of metal (gold and silver) produced	$19 29
Average yield per cubic yard of gravel	0 1019
Average amount of gravel washed per inch, cubic yards	1 48

The following tabular statements show the workings of a mine on four per cent. grades, high banks, and with great hydrostatic pressure. The advantages of heavy grades and pressure over the minimum La Grange grades are clearly shown by the quantity of material moved, and a comparison of the work and costs will be of interest to those engaged in hydraulic mining (see Table XLVIII.)

TABLE XLVIII.

Details of Work at No. 8 Claim, North Bloomfield Co.

	1874–1875.			1875–1876.			1876–1877.		
	Total.	Per cu. yd.	Per in. Water.	Total.	Per cu. yd.	Per in. Water.	Total.	Per cu. yd.	Per in. Water.
Cu. yds. Gravel moved.	1,858,000	....	4.8	2,919,700	....	4.17	2,293,900	....	3.86
Yield................	$74,271 77	3.99 cts.	19.19 cts.	$192,735 73	6.60 cts.	27.53 cts.	$290,775 42	12.68 cts.	48.87 cts.
Expenses:									
Labor..............	$22,790 39	1.23 cts.	5.89 cts.	$40,975 85	1.40 cts.	5.85 cts.	$53,742 78	2.34 cts.	9.03 cts.
Explosives.........	2,944 94	0.16 "	0.76 "	10,279 73	0.35 "	1.47 "	25,376 16	1.11 "	4.26 "
Blocks............	3,007 26	0.16 "	0.78 "	5,212 62	0.18 "	0.75 "	5,750 43	0.25 "	0.97 "
Material...........	5,663 89	0.30 "	1.46 "	9,250 46	0.32 "	1.32 "	10,158 72	0.44 "	1.71 "
Water...........	14,480 40	0.78 "	3.74 "	21,740 97	0.75 "	3.11 "	21,765 88	0.95 "	3.66 "
General...........	4,201 95	0.23 "	1.09 "	7,364 12	0.25 "	1.05 "	25,266 11	1.10 "	4.25 "
Total........	$53,088 83	2.86 cts.	13.72 cts.	$91 823 75	3.25 cts.	13.55 cts.	$142,060 08	6.19 cts.	23.88 cts.
Days' Run...........	295—com. Jan. 1, end. Oct. 14.			342—com. Nov. 13, end. Oct. 18.			318—com. Nov. 26, end. Oct. 13.		
Grade of Sluices......	6½ inches to 12 feet.			6½ inches to 12 feet.			6½ inches to 12 feet.		
Height of Banks.......	180 feet.			260 feet.			318 feet.		
Inches of Water.......	386,972.			700,000.			595,000.		

TABLE XLIX.

Classification of Mines and Mining Expenses.

Class I.—Mines with Grades 1¾ to 2¼ per cent:

Banks 20 to 80 feet high; many cobbles; few boulders; cuts light; material easily washed; worth 8 cts. to 16 cts. per cubic yard.

Operating expenses 35 to 60 per cent. of gross yield, segregated as follows:

Labor	60	per ct.
Material	16	"
Water	13	"
Explosives, bank powder	1	"
" high-grade	..	"
General	10	"
	100	"

Class II.—Mines with Grades 4 to 4¼ per cent:

Banks 50 to 150 feet high; few boulders; cuts not hard; considerable bank blasting; material worth 20 cts. to 27 cts. per cubic yard.

Operating expenses 45 to 52½ per cent. of gross yield, segregated:

Labor	42	per ct.
Material	13	"
Water	17	"
Explosives, bank powder	17	"
" high-grade, caps and fuse	2	"
General	9	"
	100	"

Class III.—Mines with Grades 4¼ to 4⅔ per cent.:

Banks 20 to 100 feet high; many boulders; cuts hard cement gravel; blasting; material worth 30 cts. to 45 cts. per cubic yard.

Operating expenses 55 to 65 per cent. of gross yield, segregated:

Labor	54	per ct.
Material	13	"
Water	15	"
Explosives, bank powder	7	"
" high-grade, caps and fuse	3	"
General	8	"
	100	"

Class IV.—Mines with Grades 4½ to 5 per cent.:

Banks 100 to 350 feet high; many boulders; hard cuts; material worth 5 cts. to 12 cts. per cubic yard.

Operating expenses 30 to 40 per cent. of gross yield, segregated:

Labor	54	per ct.
Material	11	"
Water	15	"
Explosives, bank powder	1	"
" high-grade, caps and fuse	7	"
General	12	"
	100	"

NOTE.—This estimate is based on the supposition that each company owns its water. Wages $2 50 per diem.

TABLE L.

Yield of Gravel at important Hydraulic Claims in California, according to verified Reports.

Name of Claim.	Location.	Cubic Yards Washed.	Gross Yield.	Yield per Cub. yd.	Height of Banks in ft.	Report of	Remarks.
				Cents.			
American Co......	Sebastopol, Nev. Co.	5,171,834	$1,241,240 30	24.	120	H. Smith, Jr.	
No. 8, 1870–74.	North Bloomfield, "	3,250,000	94,250 00	2.9	150	"	Paid a profit of $2,232 84.
" 1874–75. ...	" " "	1,858,000	74,271 77	3.9	180	H. C. Perkins...	
" 1875–76.	" " "	2,919,700	192,735 73	6.6	260	"	
" 1876–77. ...	" " "	2,293,930	290,775 42	12.7	265	"	
North Bloomfield..	" " "	30,000,000	2,610,000 00	8.7	150–350	"	
French Corral.....	French Corral, "	4,200,000	1,745,500 00	41.5	20–100	" ...	The greater part of the top gravel had been removed previously.
Manzanita	Sweetland, "	5,780,000	1,489,000 00	26.	50–150	" ...	About one-third of the top gravel had been removed previously.
McCarty's.........	Columbia Hill, "	3,000,000	345,663 10	4.3	....	J. D. Hague.	
Sicard.....	Patricksville, Stan. Co.	155,347	20,197 07	13.	38	J. Messerer......	Top gravel.
Delaney...........	" "	....	....	....	... .	J. L. Jernegan.	
Chesnau...........	" "	27,250	11,009 00	40.4	18	A. J. Bowie, Jr.	
"	" "	71,810	9,847 48	13.	55	J. Messerer.	
"	" "	284,932	47,781 73	16.	12–62	"	Aggregate of 7 surveys checked by 1 survey, June, 1874, to October, 1876.
"	" "	338,880	62,980 37	18.6	60	A. J. Bowie, Jr.	Includes the last.
New Light	" "	667,347	45,511 81	6.8	35	"	Drifted previously in places.
"	" "	683,244	45,444 65	6.6	24–60	J. Messerer......	Aggregate of 5 surveys checked by 2 surveys
Johnson...........	" "	196,632	9,148 27	4.6	30	A. J. Bowie, Jr.	
New	" "	17,796	773 72	4.3	42	"	
Kelley	La Grange, "	88,660	3,406 33	4.	85	"	Result obtained from cleaning out a deep hole.
"	" "	351,152	43,153 26	12.3	75	"	
"	" "	701,685	15,770 34	2.2	100	"	Previously drifted. Heavy blasting. No profit.
New Kelley.......	" "	161,032	8,852 31	5.5	40	J. L. Jernegan...	Upper bench gravel.
"	" "	252,614	35,012 33	13.8	65	" ...	Top and bottom gravel.
"	" "	1,000,000	64,550 27	6.4	40–65	" ...	Includes the two last data.
French Hill	" "	252,614	35,136 72	13.8	45	" ...	Winter of 1876–77.
"	" "	676,968	90,186 19	13.3	10–48 average 30	J. Messerer......	Aggregate of 5 surveys checked by 2 surveys, May, 1874, to October, 1876.
"	" "	1,020,347	188,433 11	15.5	30	A. J. Bowie, Jr.	Includes the last and also early workings, of which portions had been previously drifted.
Light	" "	746,640	64,714 27	8.6	48	"	Banks contained several thick strata of sand.
Blue Point	Smartsville, Yuba Co..	93,044	115,728 17	122.	[illegible]	H. Smith, Jr.	
Green Flat	[illegible]						

APPENDIX.

APPENDIX A.

SAN FRANCISCO, CAL., May 26, 1884.

A. J. BOWIE, JR., ESQ., *Present:*

DEAR SIR: You will find herewith a statement of the produce of gold in the United States since its discovery in this State in January, 1848, to the close of the fiscal year ending June 30, 1883, prepared by me at your request.

The imperfect methods of collecting and preserving such data in this country are so well known to statisticians and others as to scarcely require any apology for the inaccuracies of these estimates or the indulgence of your readers. I have long been satisfied that the produce of the precious metals in this country, as well as in others, has been considerably exaggerated, and that the tendency to over-estimation is inherent in the methods adopted. My long connection with the mining industries of this coast, however, through metallurgical operations of great magnitude, enables me to eliminate some of the inaccuracies which have crept into published statements, and which have been adopted and repeated by subsequent statisticians.

Undoubtedly the most reliable method of determining the produce of this country in the aggregate is that based upon the deposits of "domestic" gold made at the several mints, as stated in the directors' reports, and the exports of uncoined domestic bullion, as shown by those

of commerce and navigation; though in its distribution both of these reports are necessarily more or less defective in detail, and the latter more particularly contain many palpable errors and omissions.

In order to conform to the data derived from these reports I have stated my estimates in fiscal years instead of calendar years, which are usually adopted by other statisticians. As I only have the mint reports as far back as 1855, I have not the details of foreign gold, old United States gold coin, jewellers' bars, and old plate deposited from 1848 to 1854. I have, therefore, estimated these items for this period at five millions, which I find to be about the excess of the coinage over the "domestic" gold deposited, as shown in the "Summary" tables of the report of 1873. In the navigation reports the uncoined gold exported was not separated from that of gold coin prior to 1855. I have, therefore, estimated the amount for these seven years at $88,479,269, including the $33,479,269 of fine bars made at the Philadelphia mint in 1853 and 1854 and not accounted for in the coinage.

It may be well here to note also another fact which I think has been generally ignored or overlooked, and that is the large amount of private coinage made here by the old United States Assay Office and other coiners from 1849 to 1855, which was almost our only currency on this coast during that period. From the best information I can obtain on this point there could not have been much less than $60,000,000 thus coined for the seven years embraced. Much of this, however, was exported as soon as made, but there could not have been much less than $25,000,000 or $30,000,000 in circulation when the mint here went into operation, April 1, 1854. It then disappeared very rapidly, and I have eliminated the amount entirely by deducting it from the apparent produce of the years 1854, 1855, and 1856, and have added it to that of previous years, distributing it to the best of my judgment. In addition to this there should be added to the ascer-

tained produce of these earlier years an appreciable amount for what was taken out of the country in private hands. In consequence of the high rates charged by steamers in those days on the export of treasure (5 per cent. and primage), a very large amount was thus taken from the country. For several years the deposits at the Eastern mints exceeded by ten or fifteen millions annually the entire exports from this city, as shown by the Custom-House records. As every steamer carried from five hundred to one thousand passengers, no inconsiderable amount must have gone abroad in the same way. At a later period, say from 1862 to 1872, more or less gold was thus taken out of the country by returning Chinese, but never to the extent some have supposed. Nearly the whole of this gold was obtained from the establishment of which I was the manager, and I therefore speak advisedly.

It may be well to explain here also the causes of the marked decline in the produce of California gold in certain years. That of 1857 was largely due to the great excitement and resulting exodus from our mining districts incident to the Frazer River discoveries in British Columbia. The rapid decline which is noticeable from about 1863 was due, in part, to the two excessively dry years of 1862–63 and 1863–64, but to a still greater extent to the great loss of mining population resulting from the silver discoveries in Nevada—not less than from fifteen to twenty thousand of our population leaving for that State within a few years following these discoveries. The increase in California gold noticeable from about 1878 is mainly due to the produce of the Standard and other mines in the Bodie district.

While stating the produce of California at about $1,100,000,000, my belief is that it does not exceed $1,050,000,000, if so much. I can trace to this city at least $25,000,000 of uncoined foreign bullion, principally from British Columbia, which has not been accounted for by deposits at the mint or re-exports. I personally know

that much the larger portion of this gold went into the private refinery, and subsequently into the mint as "fine gold" from that establishment. Again, the directors' reports do not designate localities at the mint here prior to 1862, and up to that date all domestic gold has been credited to California. At the Philadelphia mint the first receipts of gold from Oregon were in 1853. As all gold from that State was first shipped to this city, doubtless large amounts went into the mint here, and that which did not was exported East under the stamp of some San Francisco assayer and there credited to California. From about 1864, and for a number of years subsequent thereto, heavy shipments also set in from Idaho and Montana *via* Oregon, ranging for quite a period from five to eight millions per annum. From 1862 to 1883 nearly $40,000,000 of domestic gold is credited at the mint here to "other States and Territories"; and as the private refinery and the other assay offices did a much larger business in the aggregate than the mint, it is fair to presume that at least an equal amount of this gold went into these establishments, and its identity was thus destroyed before it reached the mints. I therefore consider it a very low estimate to say $25,000,000 of this gold has been credited to California through fine gold from private refineries and assayers' imported bars. This, however, does not affect the accuracy of the statement so far as the aggregate result is concerned, but only its distribution.

In the analysis I have been compelled to make of the exports of uncoined domestic treasure, a suspicion I have long entertained has been fully confirmed, and that is that a very considerable amount of the gold contained in the produce of our silver-mines has been exported under the *silver valuation*. This is clearly evident from the fact that in quite a number of years the gold so contained, and not accounted for by "gold parted" "from silver" at the mints and private refineries, exceeds considerably the entire exports of uncoined domestic gold.

In the summary statement which here follows it will be observed that I have stated the amount of gold consumed in the arts, for the period considered, at $50,000,000. I am satisfied that this is in excess of the facts. I have on several occasions made a partial investigation of this question for my own information, and the results have always impressed me with the idea that the popular impressions upon this subject were very much exaggerated. Native gold is absolutely unfitted for the arts without refining, and, with the exception of a small amount of quartz jewelry and a few curiously shaped specimens of placer gold, is not employed for such purposes to any appreciable extent. The amount so employed is, therefore, almost fully accounted for by the deposits at the various mints, and should be considered with reference to the entire stock of gold in the world, and not confined to the current annual produce. The Director of the Mint, in his report of 1879, gives the results of his investigations of this question, as shown by the operations of the United States Assay Office at New York for the seven years from 1873 to 1879, both inclusive. According to this statement it would appear that for this period $24,780,884, or $3,540,000 per annum, had been obtained from this office for manufacturing purposes. By analyzing the operations of that institution, however, it will appear that not much more than $1,500,000 per annum is chargeable to the current annual produce of domestic gold. Succinctly stated, these operations were as follows:

Gold of domestic production deposited, $48,477,238; fine gold sent to Philadelphia for coinage, $59,920,443 (excess, $11,443,205); receipts of foreign gold and United States gold coins for recoinage, $37,322,340; jewellers' bars, old plate, etc., $3,690,834. By deducting this latter sum we have left $21,090,050 as the amount of *new* gold going into the arts. Apportioning this to the total receipts, we have $11,916,000, or $1,702,000 per annum, to be charged to domestic gold, and $9,174,000 to be charged

to gold from other sources. But for the same period the receipts of jewellers' bars, etc., at the Philadelphia mint exceeded all the fine bars made by that institution by some $1,351,143, or $193,020 per annum; and the operations of these two establishments are so intimately connected that they should be considered together. Deducting this excess leaves only $1,500,000 per annum to be charged against the current annual produce. The business has greatly increased within the past few years, but I am satisfied that the average of these seven years is considerably above that of the whole period under consideration. In this city, where the gold thus employed is obtained entirely from the private refinery, it has not, until within a year or two past, exceeded $25,000 per annum. But it has now increased to from $120,000 to $150,000.

I should explain, perhaps, that in the statement of gold parted from silver at the mints I have added to the amount as shown by the director's summary statement the amount credited at the Carson mint to "Nevada," as nearly the whole amount so credited evidently came from Comstock bullion.

By deducting from the aggregate deposits, as stated in this summary, the deposits prior to 1848 ($12,808,771) and the unparted bars made at the other assay offices and not redeposited at New York or Philadelphia, we have as the whole amount of domestic gold deposited at the mints and New York Assay Office since 1848, $1,179,824,781.

To wit: From California.....	$723,043,793	
" Other States & Territories..	171,482,218	
" Parted from silver bullion..	39,584,350	
" Private Refineries, fine gold	245,714,420	
		$1,179,824,781

Amount brought forward		$1,179,824,781
Foreign gold, U. S. gold coin, jewellers' bars, etc		351,735,237
Total deposits from all sources		$1,531,560,018
Total gold coinage	$1,264,623,632	
Uncoined bullion on hand June 30, 1883, estimated	65,000,000	
Mint deposits consumed in arts	50,000,000	
Mint deposits to be accounted for in exports	151,936,386	
		$1,531,560,018

The operations of the private refineries here from 1865 to 1883 have amounted to $265,886,266, of which $243,597,532 was deposited in the mint and $22,288,734 sold for export. Of the whole amount received $191,992,266 was in gold dust and bars, and $73,894,000 was parted from silver. I have distributed these amounts to the best of my judgment. Making the résumé in another form, we have:

Total gold coined, as above	$1,264,623,632
" uncoined gold exported	463,943,938
" uncoined gold on hand and consumed in arts	115,000,000
	$1,843,567,570
Less foreign gold, etc., as above	351,735,237
Total produce of domestic gold	$1,491,832,333
My estimates as per statement	1,469,753,117
Difference	$22,079,216

This difference is due to the foreign gold credited to domestic sources in mint reports, through fine gold from private refineries, but which I have eliminated.

Very truly yours, etc.,

[Signed] LOUIS A. GARNETT.

Produce of Gold in the United States from its discovery in California, January, 1848, to June 30, 1883. Stated in Fiscal Years.

Years.	Gold produced in State of California.	Gold produced in other States and Territories.	Total produce of Gold-Mines.	Gold contained in Silver Produce.	Grand Total Produce from all sources.
1848....	$245,301	$851,274	$1,096,575	....	$1,096,575
1849....	10,151,360	927,684	11,079,044	....	11,079,044
	10,396,661	1,778,958	12,175,619	....	12,175,619
1850....	41,273,106	665,217	41,938,323	....	41,938,323
1851....	75,938,232	602,380	76,540,612	....	76,540,612
1852....	81,294,700	712,263	82,006,963	....	82,006,963
1853 ...	67,613,487	508,564	68,122,051	....	68,122,051
1854...	69,433,931	251,627	69,685,558	....	69,685,558
	335,553,456	2,740,051	338,293,507	....	338,293,507
1855....	55,485,395	312,364	55,797,759	....	55,797,759
1856....	57,509,411	369,031	57,878,442	... .	57,878,442
1857....	43,628,172	143,053	43,771,225	... .	43,771,225
1858....	46,591,140	386,028	46,977,168	....	46,977,168
1859 ...	45,846,599	366,957	46,213,556	....	46,213,556
	249,060,717	1,577,433	250,638,150	....	250,638,150
1860....	44,095,163	875,878	44,971,041	$50,000	45,021,041
1861....	41,884,995	2,831,895	44,716,890	800,000	45,516,890
1862 ...	38,854,668	3,989,210	42,843,878	2,150,000	44,993,878
1863....	23,501,736	7,474,808	30,976,544	4,350,000	35,326,544
1864....	24,071,423	8,372,115	32,443,538	5,300,000	37,743,538
	172,407,985	23,543,906	195,951,891	12,650,000	208,601,891
1865....	17,930,858	9,920,244	27,851,102	5,500,000	33,351,102
1866....	17,123,867	12,086,941	29,210,808	4,650,000	33,860,808
1867....	18,265,452	13,169,117	31,434,569	5,700,000	37,134,569
1868....	17,555,867	7,942,116	25,497,983	4,000,000	29,497,983
1869....	18,229,044	7,607,698	25,836,742	3,550,000	29,386,742
	89,105,088	50,726,116	139,831,204	23,400,000	163,231,204
1870....	17,458,133	7,907,569	25,365,702	3,700,000	29,065,702
1871....	17,477,885	7,813,419	25,291,304	5,500,000	30,791,304
1872....	15,482,194	6,975,843	22,458,037	6,900,000	29,358,037
1873.. .	15,019,210	7,213,768	22,232,978	12,000,000	34,232,978
1874. ..	17,264,836	6,863,012	24,127,848	11,500,000	35,627,848
	82,702,258	36,773,611	119,475,869	39,600,000	159,075,869
1875....	16,876,009	5,572,299	22,448,308	13,800,000	36,248,308
1876....	15,610,723	5,511,272	21,121,995	18,500,000	39,621,995
1877....	16,501,268	8,862,694	25,363,962	18,300,000	43,663,962
1878....	18,839,141	9,755,213	28,594,354	19,000,000	47,594,354
1879....	19,626,654	10,421,948	30,048,602	9,000,000	39,048,602
	87,453,795	40,123,426	127,577,221	78,600,000	206,177,221
1880 ...	20,030,761	9,209,033	29,239,794	6,000,000	35,239,794
1881....	19,223,155	10,139,136	29,362,291	6,000,000	35,362,291
1882....	17,146,416	8,468,141	25,614,557	5,000,000	30,614,557
1883....	17,256,873	8,586,141	25,843,014	4,500,000	30,343,014
	73,657,205	36,402,451	110,059,656	21,500,000	131,559,656
Totals..	$1,100,337,165	$193,665,952	$1,294,003,117	$175,750,000	$1,469,753,117

APPENDIX B.

FINENESS OF PLACER GOLD.

Mine.	Locality.	Fineness.	Remarks.
Alpha	Nevada Co.	.940 to .950	Gold flattened in scales.
American Hill	" "	.934	
Brush Creek	" "	.820	
Manzanita	" "	.925 to .930	Gold coarse.
French Corral	" "	.930 to .950	Gold fine.
Badger Hill	Plumas Co.	.925 to .950	Gold coarse on bed-rock.
Mumford Hill	" "	.945	
Michigan Bluff	Placer Co.	.835 to .871	Gold coarse.
Cariboo Diggings	" "	.774 to .800	
Cement Hill Claims	" "	.883	Gold well rounded and smooth.
Cedar Claim No. 2	" "	.800 to .961	Gold* from blue and red gravel respectively.
Cherokee Flat	Butte Co.	.958 to .968	Gold from upper gravel sometimes reaches .980 fine.
Cañon Creek	Sierra Co.	.942 to .965	
Cañon Creek	" "	.800	Bed of the creek.
Goodyear's Bar	" "	.884	
North Yuba	" "	.835 to .890	
Eureka Mines (near Downieville)	" "	.920 to .930	
Mugginsville	" "	.930 to .934	Gold coarse like shot.
Fir Cap	" "	.836	
Monte Christo	" "	.914	
Craycroft's	" "	.939	
Gold Lake	" "	.925	
North Fork of North Yuba	" "	.885	
South Fork of North Yuba	" "	.864	
Hog Cañon	" "	.864	
Bald Mountain	" "	.926 to 936.	Gold coarse, in flakes.
Jim Crow Cañon	" "	.926	
Niagara Consolidated	" "	.916 to .918	
Kelley	Stanislaus Co.	.873 to .899	
French Hill	" "	.926 to .954	
Light Claim	" "	.936 to .951	
Chesnau	" "	.895 to .945	
Johnson	" "	.935 to .950	
Sicard	" "	.934 to .943	

* Gold very fine and scaly on bed-rock. Out of 650 diamonds found in this deposit only one had as great a value as $250.

FINENESS OF PLACER GOLD—*Continued.*

Mine.	Locality.	Fineness.	Remarks.
Camptonville........	Yuba Co.	.930 to .935	
Galena Hill.........	" "	.940	
Young Hill..........	" "	.940	
" "	" "	.925	
Railroad Hill........	" "	.925	
Depot Hill..........	" "	.910	
Indian Hill..........	" "	.925	
Oaks Valley....... } Dad's Gulch....... }	" "	.890 to .880	
High Point..........	" "	.940	
Oregon Creek.......	" "	.880	
Pike City...........	" "	.740	
Brush Creek Co.....	" "	.820	

According to King in "U. S. Geol. Survey Report," Second Annual Report, 1880–81, p. 379, the fineness of specimens of California gold as determined by him was as follows:

No. of Mines examined.	Locality.	Fineness.
5	Butte Co.	.900 to .970
1	Calaveras Co.	.850 to .960
5	Del Norte Co.	.875 to .950
1	El Dorado Co.	.980
2	Humboldt Co.	.726 to .940
5	Placer Co.	.784 to .960
5	Plumas Co.	.846 to .936
1	Shasta Co.	.885
15	Siskiyou Co.	.749 to .950
1	Stanislaus Co.	.920
10	Trinity Co.	.875 to .927
Total...51		.726 to .980

Eighty specimens averaged .883.6 fine (p. 382). Dana's "Mineralogy" says: "California gold fineness averages .875 to .885. Average, .880."

King places the average fineness of gold from the different parts of the United States as follows:

California	.883.6
Colorado	.820.5
Dakota	.923.5
Georgia	.922.8
Idaho	.780.6
Montana	.895.1
Oregon	.872.7
All the United States	.876

NOTE.—The larger portion of this table was compiled from Whitney's "Auriferous Gravels."

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